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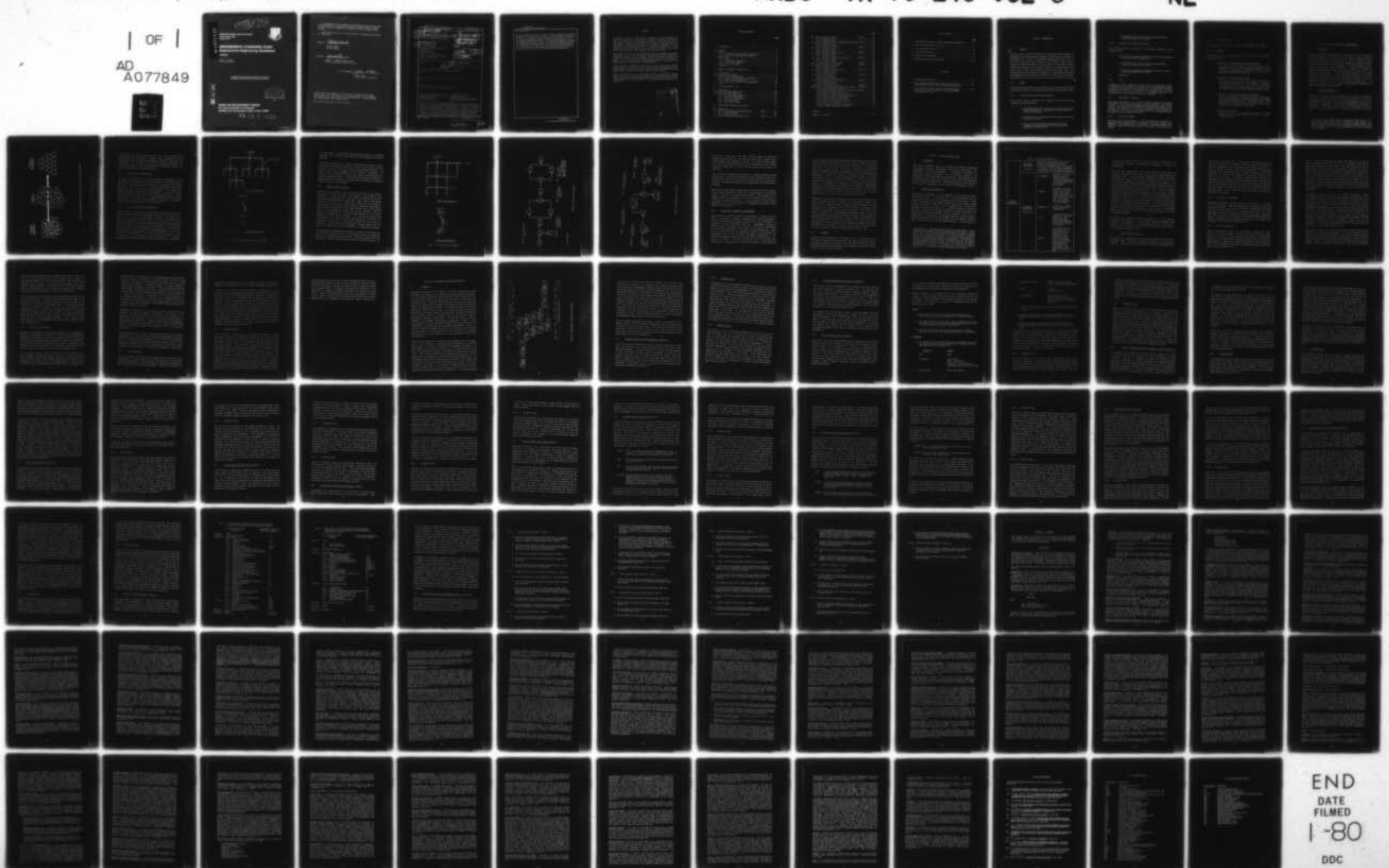

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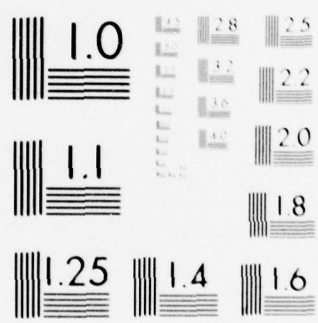

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Final Technical Report
October 1979

REQUIREMENTS STANDARDS STUDY
Requirements Engineering Guidebook

LOGICON

Daniel G. Smith
Paul B. Merrithew

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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This report is one of three volumes which provide information and guidance for defining and analyzing military system/segment specifications and development specification requirements (MIL-STD-490/483 (USAF)). Volume I is a technical overview describing the purpose of the study, the technical approach and a history of Air Force system engineering management. It summarizes the results of the study: a Requirements Engineering Guidebook, and example using the Guidebook, associated automated tool capabilities, automated tool design approaches, and recommendations on implementing the Guidebook in the (Cont'd)

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Air Force systems acquisition life cycle. Volume II expands upon the material summarized in the first volume. Volume III is the Requirements Engineering Guidebook. The Requirements Engineering Guidebook describes the characteristics of good requirements, the various system requirement types, and the requirements engineering procedures. The requirements engineering procedures are described in the form of a procedural flow with accompanying guidelines and standards for performing fourteen requirements engineering activities. Each requirements engineering activity is supplemented by a description of the specific issues to be addressed during the first two phases of the Air Force acquisition life cycle - the Conceptual and Validation Phases.

PREFACE

This report is one of three volumes prepared to assist government and contractor personnel in managing and performing system requirements definition and analysis: requirements engineering. The primary results of this study has been the definition of guidelines and standards for requirements engineering (Requirements Engineering Guidebook) and the identification of automated aids to support the application of the guidelines and standards during the initial phases of the Air Force system acquisition life cycle - the Conceptual and Validation Phases.

This study reflects Logicon's experience with an automated requirements engineering tool applied in support of the acquistion of a large Air Force surveillance system. The Requirements Engineering Guidebook reflects the needs of an Air Force System Program Office acquisition environment; however, the basic requirements engineering principles and guidance are easily adapted to other acquisition environments.

This report was prepared by Logicon for the Air Force Systems Command (AFSC), Rome Air Development Center (RADC), Software Engineering Section. Administrative review and technical coordination of this report have been accomplished for RADC by Mr. Michael Landes (project officer).

Review of this report was accomplished at RADC, by Electronic Systems Division (AFSC/ESD) personnel at Hanscom, AFB, and by Logicon personnel. Special thanks to the many reviewers and for the patience and skills of Ms. Marcia Brehm and Ms. Deborah Queen for the technical typing, proofing, and revisions.

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SECTION 1 INTRODUCTION

1.1 Purpose

The Requirements Engineering Guidebook provides guidance and standards for government and private engineering personnel in defining and analyzing the requirements for a system. This guidebook addresses the initial phases of Air Force system acquisition (Conceptual and Validation Phases) and is intended to provide guidance for the acquisition of large-scale systems. However, the guidance can be applied to smaller, less complex systems and can be used in acquisition environments other than the Air Force. This document contains the guidelines and standards for requirements engineering and documentation and provides the framework for tailoring the requirements engineering activities to the specific needs of individual programs.

1.2 Scope

This guidebook supplements the engineering requirements and guidance provided by AFR 800-3, MIL-STD-499A, MIL-STD-490, and MIL-STD-483 (USAF).

1.2.1 Program Office Requirements Engineering

This document provides guidelines and standards for Air Force program offices in the following areas:

- Performing requirements engineering activities and producing system documentation in conjunction with preparation of solicitation documents.
- Contracting for the performance of the preceding activities by support contractors.
- Contracting for requirements engineering during the subsequent phases after contract award by the prime contractor or subcontractors.

- establishing the criteria for evaluating requirements engineering progress and products.

1.2.2 Contractor Requirements Engineering

This document provides information to government contractors in the following areas:

- Performing requirements engineering activities and producing system requirements documentation.

- Establishing the criteria for evaluating requirements engineering progress and products.

- A means of establishing an engineering effort and a System Engineering Management Plan (SEMP)

1.3 Definitions

1.3.1 System

A composite of items, assemblies (or sets), skills, and techniques capable of performing and/or supporting an operational (or non-operational) role. A complete system includes related facilities, items, material, services, and personnel required for its operation to the degree that it can be considered a self-sufficient item in its intended operational (or non-operational) and/or support environment. (AFR 65-3)

1.3.2 Requirements Engineering

Requirements Engineering is an iterative process of defining the system requirements and analyzing the integrity of the requirements. This process involves all areas of system development preceding the actual design of the system. The products of the requirements engineering process can be evaluated for completeness, consistency, testability, and traceability. The essential goal of requirements engineering is to thoroughly evaluate the needs which the system must satisfy.

1.3.3 Quality Requirements

The term 'quality requirements' is used throughout this guidebook to denote system requirements which are complete, consistent, testable, and traceable. This characteristic is the result of the requirements being discretely identified and well-orgainzed as discussed in the sections to follow.

1.3.4 Other Definitions

For definitions of other terms used in this guidebook, see Appendix A.

1.4 Contents

The remainder of this guidebook consists of three sections and one appendix, as follows:

- Section 2 - Quality Requirements Characteristics.

  Provides a description of the two requirements characteristics: discrete and well organized. This discussion is followed by a description of three forms of well-organized requirements: hierarchical structures, system flows, and requirements traceability.

- Section 3 - System Requirement Types.

  Provides a concise definition of the two sets of requirements: the functional requirements set and the constraint requirements set. The functional requirements set (functions) are defined and the five constraint requirements types (performance, physical, operability, test and design) are examined and explained through example.

- Section 4 - Requirements Engineering Procedures.

  Provides the procedural framework for defining and analyzing the system requirements. The procedures consist of fourteen activities which are explained in the general context of the requirements engineering activities which occur. Each activity is followed by an explanation oriented toward the Conceptual and Validation Phase issues.

- Appendix A - Glossary.

  Provides definitions of the major terms used in Air Force System acquisitions and concludes with a list of acronyms and abbreviations.

SECTION 2 QUALITY REQUIREMENTS CHARACTERISTICS

2.1 Introduction

Quality requirements are dependent upon the analyst first identifying the discrete requirements of the system and then organizing these requirements in effective ways for further analysis. Initial documentation for identifying user system requirements may include early planning documents and specifications for similar systems, for system interfaces, and for existing or previously defined subsystems. In addition, documentation derived from engineering studies and prototyping or experimental test systems may be available. If the engineering activities have advanced beyond the planning and study stage, specification documents such as Type A and Type B specifications [1] may have already been developed. These early requirements documents usually have one prevailing characteristic: the system requirements are not typically distinguished (discrete) or collectively defined (well-organized).

2.2 Discrete Requirements

Figure 1 illustrates the first characteristic of quality requirements: discreteness. The key to identifying discrete requirements is to break the source documentation into individual parts which represent non-overlapping requirements. Requirements should then be categorized as functions the system must accomplish or system constraints (performance, physical, operability, test and design). At this point missing or incomplete

[1] In Air Force system acquistitions the functional specification is the system/segment specification (Type A, MIL-STD-483 (USAF), Appendix III) and the development specifications are Type B specifications. The Computer Program Configuration Item Specification (Type B5, MIL-STD-483 (USAF), Appendix VI) is the primary development specification addressed in this guidebook.

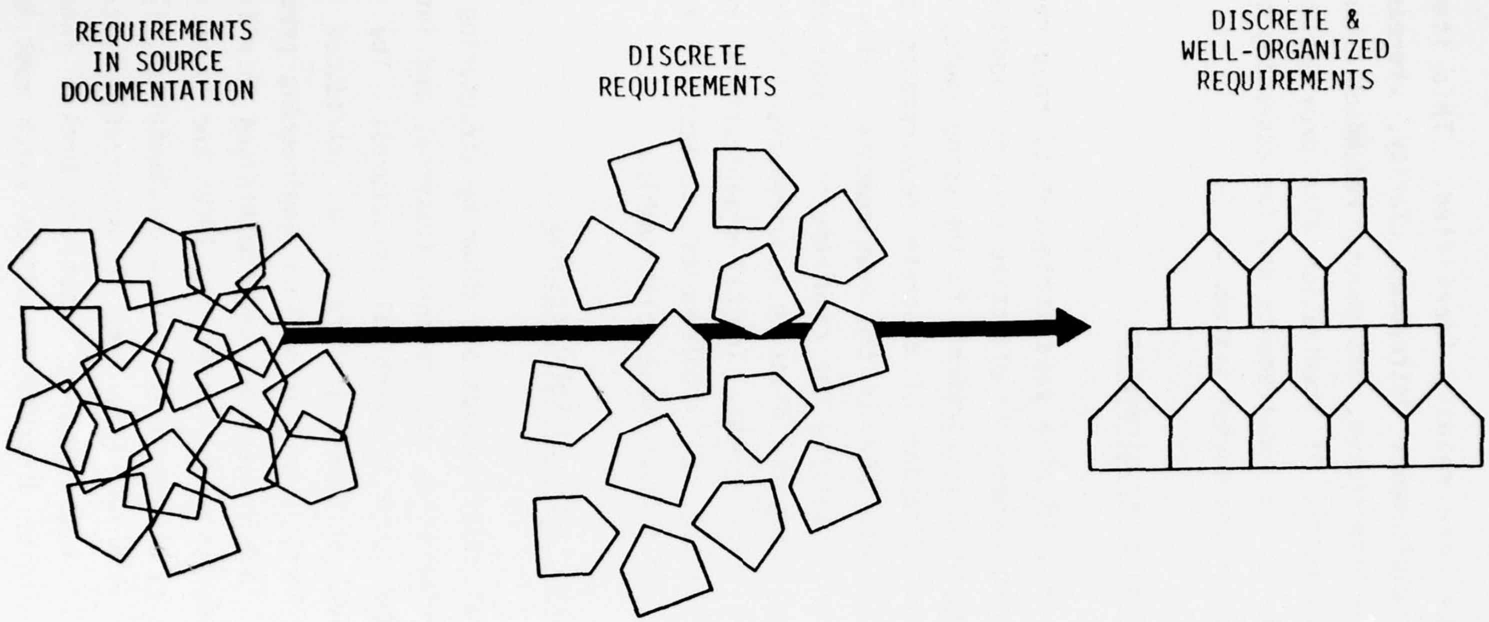


Figure 1. Development of Discrete and Well-Organized Requirements

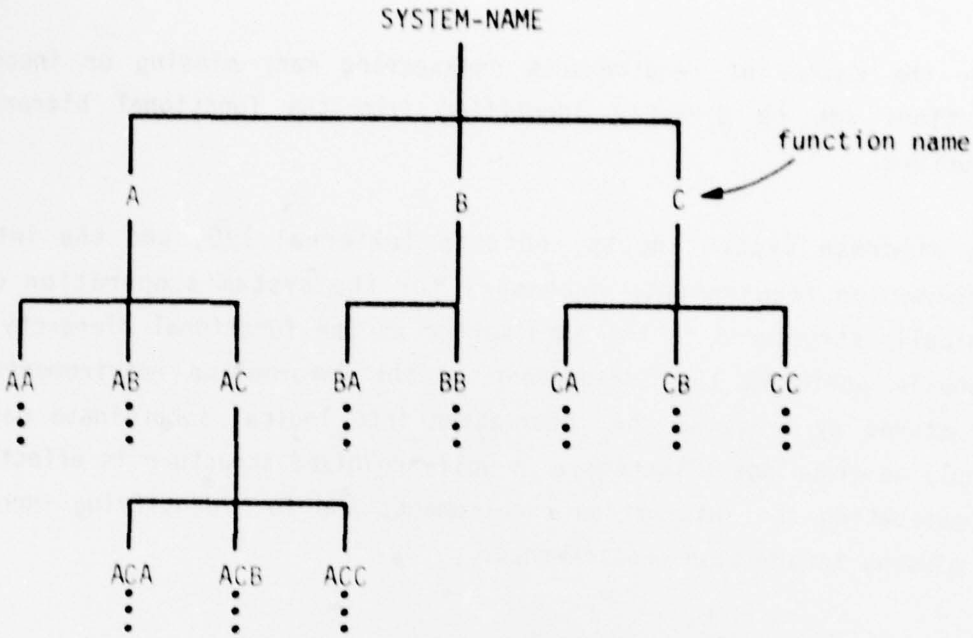
requirements can be more readily identified. This itemization and categorization of requirements introduces clarity, whereas the source documentation may be overstated, ambiguous, redundant, incomplete, and inconsistent. This process of itemization also provides the basis for verifying the quality of the requirements and for assessing the ability to test the requirements in the target system.

2.3 Organization of Requirements

The second characteristic of a good statement of requirements is the arrangement of the requirements in effective ways for additional analysis and for communicating these requirements to the using agency and to design engineers. The identification of discrete requirements provides some awareness of omissions and gaps in the requirements. This awareness is further heightened by organizing the requirements in ways which identify all the relationships among the discrete requirements (Figure 1). These relationships are of three types: logical organizational relationships, system flow relationships, and requirements traceability relationships. The following paragraphs discuss these relationships.

2.3.1 Logical Organizational Relationships

Logical organizational relationships are shown by structuring the discrete functions and the information requirements (external and internal input/output) of the system into hierarchical structures. The concept of a functional hierarchical structure (Figure 2) was introduced into military systems development through initial systems engineering practices dating back to the 1940s. This concept has been maintained in military systems development and documentation throughout the 1960s and is an integral part of the current military standards for system documentation, i.e., MIL-STD-490 and MIL-STD-483 (USAF). This form of organization provides a view of the system as an aggregate of functions broken into a logical arrangement of subordinate discrete activities which must be performed.



Graphic Representation

SYSTEM-NAME

A

AA ...
AB ...
AC ...

ACA ...
ACB ...
ACC ...

B

BA ...
BB ...

C

CA ...
CB ...
CC ...

Indented Representation

Figure 2. Functional Hierarchical Structure

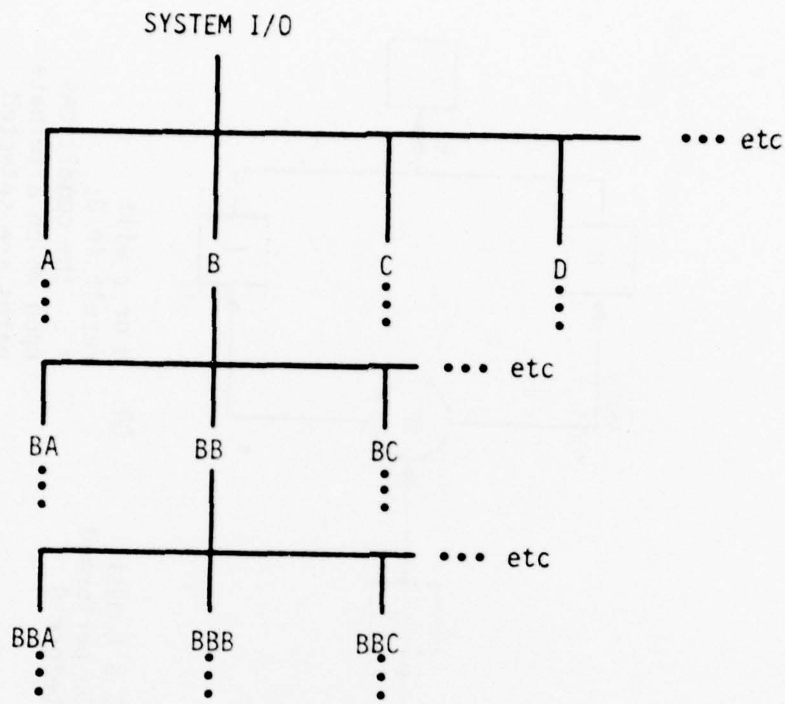
Over the course of requirements engineering many missing or incomplete functions can be directly identified from the functional hierarchical structure.

The discrete system inputs, outputs (external I/O) and the internal information requirements necessary for the system's operation can be logically structured in the same manner as the functional hierarchy. The emphasis again is the arrangement of the information requirements into structures by breaking the information into logical subordinate parts or simply as groupings (Figure 3). A well-organized structure is effective in communicating the information requirements and for identifying incomplete or missing information requirements.

2.3.2 System Flow Relationships

System flow relationships can be shown by organizing the discrete requirements in terms of control flow (Figure 4) and information flow (Figure 5). As the functions of the system are defined, the control relationships between them are identified. These control relationships describe the logical order in which the system activities should be accomplished to satisfy the system mission and operational requirements. Conditions which determine the flow direction when two or more branches occur are also represented. Control-flow analysis provides a means of viewing the system from an activity-oriented perspective and is often referred to as functional-flow analysis. As a result of this analysis the requirements are viewed in a well-organized manner and missing or incomplete functions and relationships between the functions are identified. Final control-flow documentation becomes another effective means for communicating system requirements to implementing engineers.

On the other hand, the information flow analysis (Figure 5) builds upon the I/O hierarchical structure (Figure 3) by providing a means of viewing the system as an information processing system. During this analysis the flow relationships between external system inputs and resulting outputs are



Graphic Representation

```
SYSTEM I/O
  INPUT-A ...
  OUTPUT-B
     BA ...
     BB
       BBA ...
       BBB ...
       BBC ...
       (etc)
     BC ...
     (etc)
  INPUT-C ...
  OUTPUT-D ...
  (etc)
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Indented Representation

Figure 3. I/O Hierarchical Structure

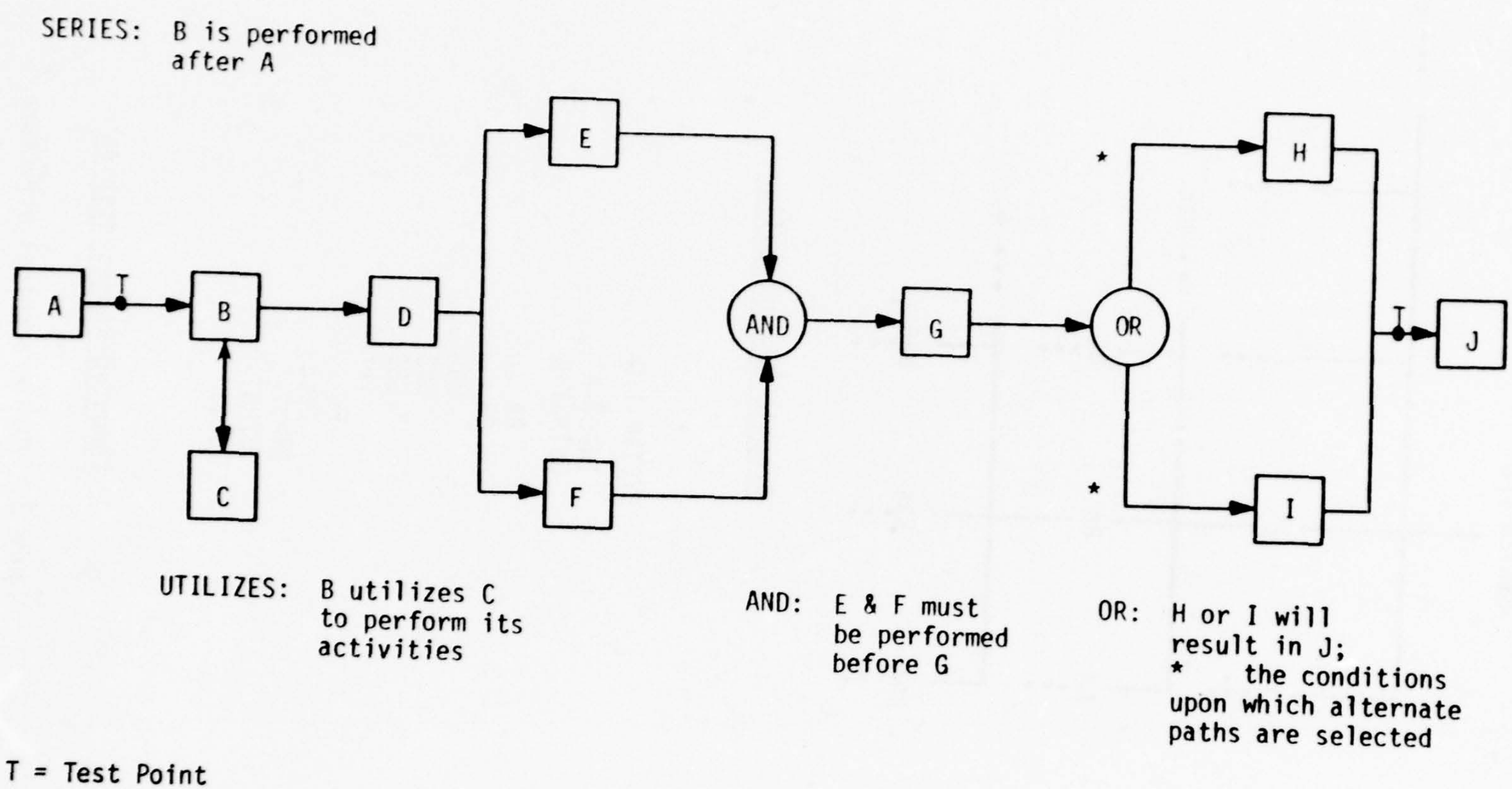

Figure 4. Control-Flow Diagram

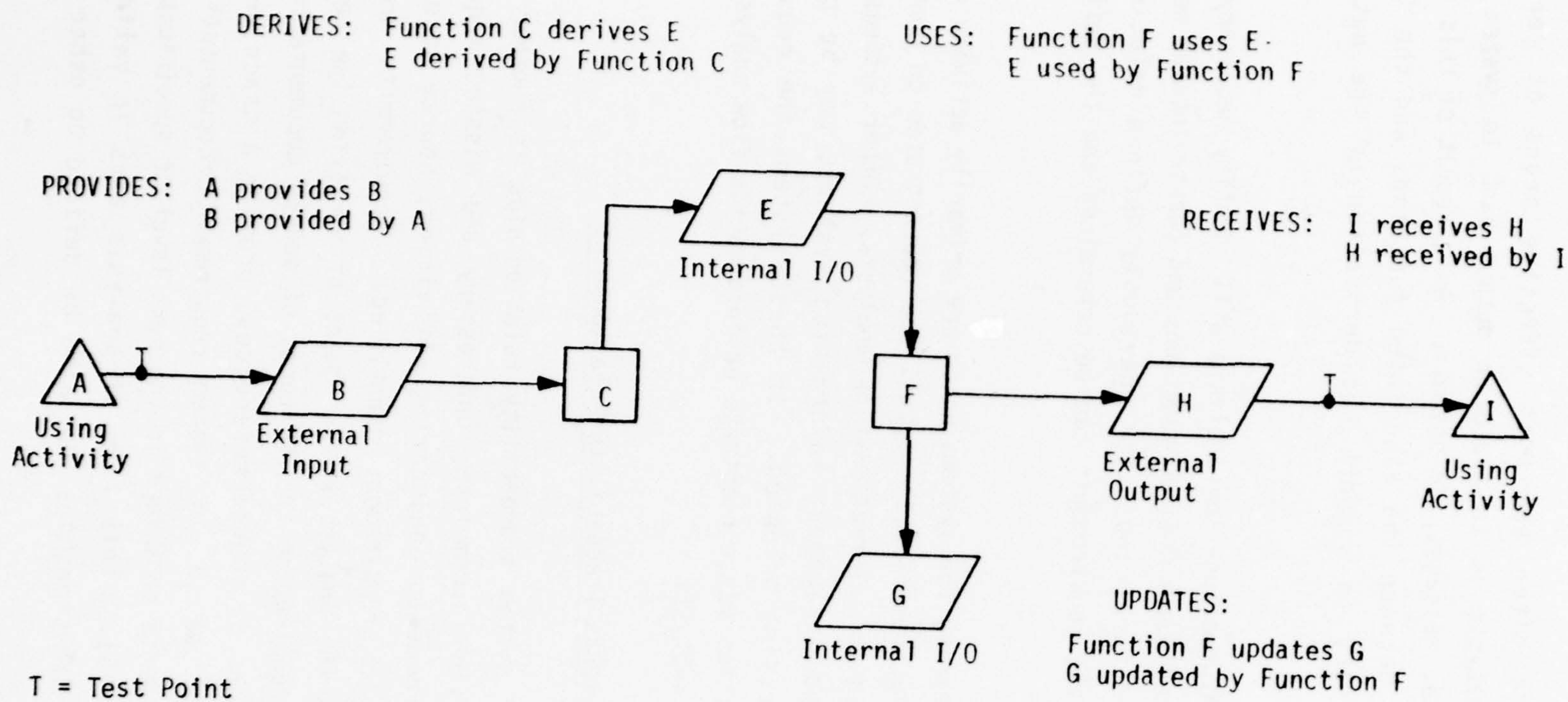

Figure 5. Information-Flow Diagram

identified. Quite often the most effective means of performing information-flow analysis is to trace an output back to system inputs, either external data, messages, or stimuli. As a result of this analysis the relationships between the associated functions and the internal information necessary to support the derivation of the output are identified.

Control-flow and information-flow analysis will identify necessary changes and additions to previously defined functions and constraints as well as to the hierarchy structures and other previously defined relationships. Missing or incomplete requirements can be determined and the deficiencies corrected.

Requirements engineering for systems which are primarily activity oriented, such as command and control systems, will be concentrated on control-flow analysis as opposed to information-flow analysis. Other systems such as communications and management information systems, may be primarily information processing oriented. In these systems the requirements engineering activities may concentrate on information-flow analysis rather than control-flow analysis.

2.3.3 Requirements Traceability Relationships

Identification of system traceability relationships is another effective means of identifying incomplete, unnecessary and missing requirements. During the requirements engineering activities, source documents are referenced for each requirement identified. Requirements traceability analysis provides the analyst with a means of verifying the requirements by linking each requirement to all forms of source documentation. These links, in the form of source references, provide a trace between the requirements from one set of system requirements documentation to the allocated requirements contained in the next level of specification; e.g., (Type A to Type B). This form of analysis aids in validating the requirements. Relationships can also be defined to other pertinent studies, analyses, and plans which are being accomplished concurrently with the requirements engineering activities, such as program management directives and plans, system sizing and timing studies, prototyping, simulations, test planning, and the like. System test requirements (quality assurance), as well as subsequent test plans, procedures, and reports, can be effectively related to the system functional-performance requirements. The links to associated system plans, analyses, and studies accomplished prior to, during and subsequent to the start of formal requirements engineering are crucial to the overall systems engineering concept. The traceability relationships also provide a bridge between requirements engineering activities and subsequent implementing engineering, since the requirements can be traced from Type A to Type B5 specifications (and other specifications) and system test plans and procedures during the later phases of the system acquisition.

Throughout the requirements engineering activities, the analyst must be able to evaluate the impact of changes to the requirements. Whatever the reason (policy, economics, study or analysis results, engineering change proposals, etc.), the analyst must be in a position to determine the ramifications of changes to the system requirements. Once the area of impact is identified in the requirements engineering products (functional and I/O hierarchies, control and information-flows, etc.) the traceability relationships provide the capability to readily identify associated impacts to the system and to trace the impacts to all other associated documentation: program directives, plans, studies and analyses, test plans, associated system specifications (Type A, Type B, etc.) and the like. The impact can be readily analyzed and the appropriate actions taken.

2.4 Summary

Discrete and well-organized requirements support the primary goal of defining the operational mission needs of the using activity while giving the analyst visibility and control over the system definition process. Discrete and well-organized requirements are prerequisites for the creation of good Type A and B specifications.

SECTION 3 SYSTEM REQUIREMENT TYPES

3.1 Introduction

The system requirement types are functional requirements, performance requirements, physical requirements, operability requirements, test requirements, and design requirements. In developing requirements or identifying system requirements from requirements documents, any combination of these requirements types may exist. Understanding the six requirement types and their use contributes significantly toward achieving quality requirements definitions. System requirements fall into two sets: the functional requirements and the constraint requirements (Table 1).

3.2 Functional Requirements Set

The functional requirements set is the backbone of the system requirements engineering process. It is within this set of requirements that the pure design-free or solution independent needs are declared. Simply stated, the functional requirements represent the total discrete system activities required to achieve a specific objective; this is most often referred to as the mission objective. A functional requirement identifies what must be accomplished without identifying any aspect concerning the means such as hardware, computer programs, personnel, facilities, or procedural data. The functional requirements represent a problem statement devoid of any overtone or specifics regarding real or conceptual solutions which satisfy any or part of the needed functions[1]. Some examples of

[1] Functions take on different meanings within three types of system documentation as required by MIL-STD-490 and MIL-STD-483 (USAF). Type A specification functions are defined for the system as a whole as defined above. Type B5 specifications define the CPCI functions to include the inputs, processing, and outputs. The Computer Program Components (CPCs) of the Type C5 specification may correspond to the functions in the Type B5 specification if the B5 requirements satisfy the computer program developer's design approach. For the purpose of requirements engineering, functions are defined to be the same as Type A specification functions. In documenting functions in Type B5 specifications, the associated inputs and outputs are included.

Table 1. System Requirement Types

SYSTEM REQUIREMENTS	FUNCTIONAL REQUIREMENTS (functions)	The set of discrete functions which identify the pure design free or solution independent needs of the system as a whole. The functional requirements identify what must be accomplished while avoiding solution statements or overtones.	
	CONSTRAINT REQUIREMENTS (Constraints)	PERFORMANCE	How well the system functions must be accomplished,such as timeliness and accuracy. Also called performance characteristics, MIL-STD-490.
		PHYSICAL	Influences the design solution in a physical manner: power, size, weight, environment, human factors, existing system interfaces, GFP, etc. Also called Physical Characteristics, MIL-STD-490.
		OPERABILITY	Reliability, maintainability, availability, dependability.
		TEST	Identify the functional, performance, physical, operability, and design requirements which will be evaluated during system integration and test.
		DESIGN	The minimum or essential design and construction requirements which are a constraint on the functional requirements of the system during the design and construction of the system end-items (CIs/ CPCIs). Also called Design and Construction, MIL-STD-490.

discrete top-level functions for an electronic system might be surveillance, tracking, identification, interceptor control, and communication.

The functional requirements are the most difficult requirements to identify. The problems arise partly from a lack of understanding of the requirement types. Without guidance, requirements engineers (government and contractor) work without a well defined and consistent set of terminology and engineering techniques for requirements engineering. The lack of requirements engineering terminology and standards allows even the best-intentioned analyst to digress from the "need" category to "how to" or solution-oriented requirement definitions. This is a natural tendency especially for any design-oriented engineer, such as a software engineer. As soon as a need is identified an immediate and more predominate solution response is quite natural. Preconceived ideas from past engineering experience or operational experience with existing systems naturally come to mind. The results are "system requirements" (functions and constraints) which are semantically riddled with solution overtones or specific design details without conscious realization or justification. The thought process simply shifts to a solution oriented position almost at the point of conceptual thought.

An example of a solution oriented statement is "...the pressure, temperature, and humidity (PTH) data shall be recorded on magnetic tape every ten (10) seconds..." In this example the basic function is a recording of PTH data, but the solution oriented feature is that the data will be recorded on magnetic tape.

3.3 Constraint Requirements Set

The second set of requirements is the constraint set which consists of five requirement types: performance, physical, operability, test, and design (Table 1). The constraint set modifies the functional requirements set.

Without the constraint set, a solution for the system functional requirements could not be achieved. Since only need is expressed in a functional requirements set, any number of solutions may be possible. In order to realize a solution, the problem identified in the functional requirements set must be constrained. However, excessive or unrealistic constraints, can eliminate all solutions or increase the technical risks and cost of the solution. Therefore, identification of the constraint requirements must be achieved with care. Whenever specific constraints are identified, there must be sufficient justification, such as an engineering analysis, which clearly shows that the constraint is reasonable, necessary, and practicable, and represents an actual requirement and not just a desirable feature. The five constraint requirement types are discussed in the following paragraphs.

3.3.1 Performance Requirements

Performance requirements identify "how well" the functions of the system must be accomplished. These requirements are the essential quantifiable statistical parameters upon which the successful accomplishment of system functions can be evaluated, such as timeliness and accuracy. The timing performance constraints include computational-solving times, countdown or event timing, and timing allocations as established through engineering analysis. An example of the performance constraints is "all displays shall be updated within 3.0 seconds after the input..."

3.3.2 Physical Requirements

Physical requirements constrain or significantly influence the design solution in a physical manner. The physical constraints include power, physical features (size and weight), environmental considerations (controlled or natural), human performance capabilities and limitations (human factors), predetermined internal and external system interfacing, use of existing equipment (off-the-shelf) and Government Furnished Property (GFP), and use of standard parts.

Power at a remote site may have to be supplied by generator or be received from utilities adjacent to the system site. If the system is airborne the power may be received from the aircraft. The power considerations may be predetermined by the situation and, therefore, constrain the solution possibilities. Again, the size and weight of equipment to be considered as part of the configuration may have to be quantitatively stated. For instance, a system which is to be installed in an existing facility, aircraft or launch vehicle would require specific weight and size requirements to be identified. Mounting location and conditions may also have to be identified. Weight and size are also important to future growth and transportability of the system components as well as installation and maintenance.

Environmental aspects are also critical physical requirements. Ranges of atmospheric pressure, temperature, and humidity (PTH) may have to be specified both in terms of the operational conditions of the system as well as non-operational conditions such as transporting the system or any of its parts which are sensitive to PTH and shock. Additional facility environmental requirements are illumination and noise levels, wind and snow and others. Human performance is identified where the design of the system should be significantly influenced by the limitations or capabilities of personnel involved with the system. Human performance requirements concern the tasks to be performed by the personnel, the time required to accomplish a task, the number of persons involved, the sustenance or life support requirements related to the tasks, training requirements, and training equipment or aids.

Other physical constraints concern predetermined interfacing with existing external or internal system components. For instance the system may be interfaced with existing communication systems such as AUTODIN or AUTOVON. Again the system may transmit or receive electromagnetic signals from other electronic devices. The system might have to interface with navigational systems. Internal interfaces are more limited in the initial requirements definition process, because their identification lends itself to the definition of the configuration items of the proposed system. However, in some proposed systems it is known very early that a particular piece of equipment must be included in the configuration and forms a part of the internal system interfaces. An example of this is deciphering equipment which the proposed system may use in order to communicate with an external system where classified information is received or transmitted.

The last two physical requirements are off-the-shelf/GFP equipment and the use of standard parts. In some systems existing equipment such as the deciphering equipment mentioned previously may be provided to the contractor for inclusion in the proposed design. Off-the-shelf equipment or GFP may be stressed to decrease risks and cost. Requirements to use standardized parts is a logistical consideration which has significant bearing on the design process. Parts control is applied more universally during the design definition process to control the selection of parts for inter- and intra- system equipment development. Parts control is more easily thought of as a program which the contractor must implement as part of his design process.

3.3.3 Operability Requirements

Operability requirements include system availability and dependability. Availability incorporates the aspects of reliability and maintainability; dependability incorporates the aspects of survivability and vulnerability (S/V) and external electromagnetic interference. Again these requirement types modify the functional requirements and constrain the problem. Each of these operability requirements categories is influenced by design related issues, policy related impact, or non-controllable factors.

Air Force Regulation 80-5 defines reliability as the probability that a part, component, subassembly, assembly, subsystem or system will perform for a specified interval under stated conditions with no malfunction or degradation that requires corrective maintenance actions. Maintainability is closely related and inseparable from reliability and is defined to be a characteristic of the design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time when the maintenance is performed using prescribed procedures and resources. Hardware reliability is usually expressed in terms of Mean Time Between Failure (MTBF) or Mean Time Between Maintenance Action (MTBM). Hardware maintainability is expressed in terms of Mean Time to Repair (MTTR). The relationship between reliability and maintainability is termed the availability of the system; this is usually expressed as a ratio between MTBF and MTTR. Reliability is not considered by many to be an appropriate term when applied to system computer programs, since certain software failures can be attributed to design deficiencies which cannot be adequately predicted and tested.

Dependability addresses the issues of system survivability and vulnerability (S/V), and external interference. Survivability is the ability of the system to achieve its mission under the conditions of a man-made hostile environment. In addition, the system may be required to operate under the conditions of interference from external electromagnetic sources (Electromagnetic Compatibility - EMC) as well as operate under threat of possible electronic countermeasures (ECM) such as spoofing and jamming.

Therefore, operability reflects many constraints upon the functional requirements set. The availability (reliability/maintainability requirements), and dependability requirements (S/V, EMC, ECM) reflect operational issues. These operability requirements are identified early in the requirements analysis activities and are expressed in the various planning documents and are reflected in specification documents for the system.

3.3.4 Test Requirements

Test requirements impact the design process and the resulting system configuration. The test requirements have been singled out from the other constraint requirements in this guidebook to emphasize the importance of the testability of the system requirements. The test and evaluation requirements are usually specific to each acquisition and will be initially identified at a high system level in early requirements documentation.

In order to test certain system requirements, a unique test must be associated with the appropriate end-item which incorporates requirement(s) to be tested. For those requirements which are inherent in a collection of end-items, the test of a requirement will be accomplished during system testing. Critical system requirements should be allocated to unique end-items, as much a possible to improve the requirements testability. Section 4 (MIL-STD-490/483 Type A and B Specifications, Quality Assurance Provisions) identifies the specific requirements for formal test and verification of the system (Type A) and subsequently its end-items (Type B). These test and verification requirements identify what specific system requirements of Section 3 of the specification must be satisfied. Test requirements, therefore, identify the functional, performance, physical, system-effectiveness, and design requirements which will be evaluated during system integration and test.

3.3.5 Design Requirements

The last form of constraints are the design requirements. These requirements represent the minimum or essential design and construction requirements which are not addressed by the four previously described constraint requirement types: the performance, physical, operability and test requirements. Like the other constraint requirements, these requirements restrain the functional requirements of the system during the design and construction of the system end-items (CIs and CPCIs). During the initial phases of systems requirements engineering (Conceptual and Validation Phases), certain design and construction standards may be specified directly or by reference to other specifications or standards. According to MIL-STD-490, the design requirements include appropriate design standards, requirements governing the use or selection of materials, parts and processing, interchangeability requirements, safety requirements, and the like. As the system development continues, engineering analysis and trade study results (as well as other engineering activities such as prototyping and simulations) may indicate the need for additional design constraints which are practicable and necessary for the system's operation and maintenance (O&M). An example of the O&M design constraint is the specification of computer programming requirements for software end-items (CPCIs): during the Conceptual Phase these design requirements are defined for the system as a whole and govern the design and construction of system functions which are implemented in software (MIL-STD-483, Appendix III).

SECTION 4 REQUIREMENTS ENGINEERING PROCEDURES

4.1 Introduction

Requirements engineering is an "iterative" process of defining the system requirements and analyzing the integrity of the requirements for completeness, consistency, testability, and traceability. As the process conti ies the system requirements are defined and analyzed in a progressively expanding manner. The definition and analysis activities will move from one area of concentration to another as the results of previous activities reveal areas needing additional work. No singular approach can be rigidly defined and applied which can take into account the many possibilities which must be considered. However, guidelines for requirements engineering and associated tasks can be defined and then tailored for specific requirements engineering applications. This section presents a general framework for requirements engineering as illustrated in Figure 6. Each block represents a unique requirements engineering activity which shall be accomplished in defining and analyzing system requirements. There is a continual interaction between the activities of each block, and although each block appears as a single activity, it is in fact part of a continuum. The selection of an actual approach for a given application is one of the tasks (BLOCK 2).

The activities identified in Figure 6 may be organized into five general steps. In step 1 (BLOCKS 1-2) pertinent source documentation is identified and reviewed. The analysis team develops a requirements engineering plan which identifies the resources required and the specific approach to be taken in performing the remaining requirements engineering tasks (BLOCKS 3-14). Step 2 involves identifying and organizing the activity structure (BLOCKS 3-5) and information structure(s) of the system (BLOCKS 6-8). The requirements engineering tasks associated with BLOCKS 3-5 are concentrated on analyzing the system source documentation in terms of activities performed by the system. If the system is primarily activity oriented, such as a command and control system, the analysis activities may be concentrated on the tasks identified in BLOCKS 3-5. If on the other hand,

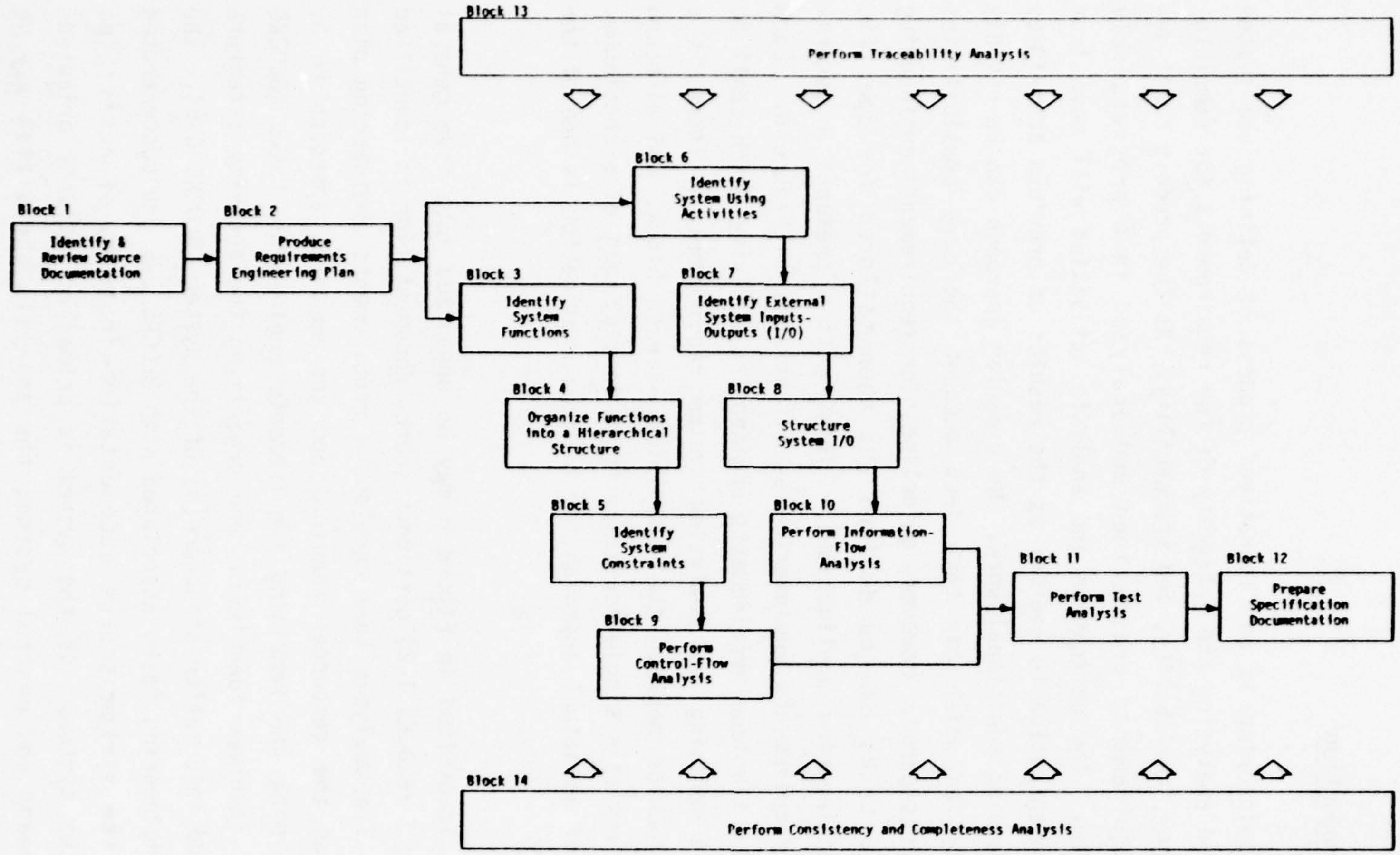

Figure 6. Requirements Engineering Procedures

the system is primarily information oriented, as in the case of a communications system or an automated data processing system (ADP) application such as a management information system, the analysis activities may be concentrated on the tasks associated with BLOCKS 6-8. The activities associated with BLOCKS 3-5 and BLOCKS 6-8 are generally done concurrently. During step 3 the flow of control between system functions (BLOCK 9) and the flow of information into, within, and out of the system (BLOCK 10) can be defined and analyzed. Step 4 involves analyzing the system requirements for testability (BLOCK 11) and preparing required specification documents (BLOCK 12). Step 5 consists of two activities which are continuously performed in conjunction with the activities of BLOCKS 3-12. Source documentation references shall be maintained for each requirement identified and traceability analysis shall be performed (BLOCK 13). Various consistency and completeness checks (BLOCK 14) shall be accomplished.

In the following paragraphs each block in Figure 6 is explained in the general context of the requirements engineering activities which occur. Following this general description is an explanation oriented to the Conceptual Phase and Validation Phase issues. The proximity of these descriptions has been chosen to communicate the subtleties between the two phases which is too often misunderstood.

4.2 Identify and Review Source Documentation (BLOCK 1)

During this task the requirements analysis team shall individually review the source documentation in order to become familiar with the overall system requirements. It may be appropriate to initiate a formal mechanism to track individual and team concerns throughout the definition and analysis activities. During the review sessions the analysis team shall perform a general evaluation of the requirement types contained in the source documentation. The review of the source documentation and the assessment of requirement types are prerequisites for developing the requirements engineering plan (BLOCK 2).

4.2.1 Conceptual Phase

The objective of the requirements engineering activities during the Conceptual Phase will be either to produce an initial system specification (Type A) from available user documentation or to determine the quality of the requirements in the initial system specification prior to the Validation Phase activities. Pertinent documentation for producing an initial system specification includes various planning and user requirements documents (PMD, PMP, ROC, SON) along with specifications for similar systems, for system interfaces, and for existing or previously defined subsystems. In addition, documentation derived from engineering studies and prototyping or experimental test systems shall be used in defining and analyzing the requirements of the system. If the engineering activities have advanced beyond the planning and study stage, the initial system specification may have already been prepared. If an initial system specification does exist, the requirements and analysis activities shall be oriented toward evaluating the system specification prior to the initiation of the Validation Phase.

4.2.2 Validation Phase

The objective of the requirements engineering activities during the Validation phase shall be (1) to refine the initial system specification (Type A) derived from the Conceptual Phase in order to authenticate and baseline the system operational requirements and/or (2) to expand and allocate the authenticated system specification requirements to system end-items (CIs/ CPCIs). The initial system specification, along with other pertinent documentation as described in the preceding paragraph, shall be used as an input to the BLOCK 1 activities in order to provide the basis for authenticating the requirements of the system. On the other hand, the authenticated system specification (Type A) shall be the input to BLOCK 1 activities leading to the allocation of requirements to system end-items (CIs and CPCIs) and the preparation of Computer Program Development Specifications (TYPE B5).

4.3 Produce Requirements Engineering Plan (BLOCK 2)

After review of the source documentation the analysis team shall determine the specific approach to accomplishing BLOCKS 3-14. This approach shall take into account all available resources including personnel, schedule, and financial considerations. The planning shall detail the methodology to be applied (tools, techniques,conventions, etc.), specific tasks to be accomplished, personnel assignments, resource descriptions, schedules and milestones, preliminary and final documentation to be produced (BLOCK 12), progress reviews and quality assurance procedures. The results shall be described in a requirements engineering plan.

If automated tools are selected to assist in the requirements definition and analysis of the source documentation, features of tool to be employed shall be determined. This selection shall insure that the analysis proceeds in a uniform manner, and the features of the automated tool satisfy the requirement types identified in the source documentation. In addition, the planning shall identify specific automated reports required during subsequent requirements definition and analysis activities and for final documentation.

4.4 Identify System Functions (BLOCK 3)

During this task the source documentation is analyzed and the system functions, necessary to control or produce the desired outputs from the available inputs, shall be identified. A function is a discrete activity within a system. The collection of discrete functions, defines the total activities which must be accomplished by the system to achieve a given objective. The functions identified shall range from high level (first possible functional breakout of the system) to detailed lower level functions which represent finite, distinct actions to be performed by system equipment, computer programs, personnel, facilities, procedural data, or combinations thereof.

The requirements definition and analysis activities associated with this task shall be oriented toward identifying the actual user functional requirements which are necessary to achieve the mission objective.

Naming a function is an important part of the requirements engineering process. Function naming conventions shall be defined (BLOCK 2) and consistently applied throughout the requirements definition and analysis activities. The following are required or recommended conventions for developing function names:

Required

- Each function shall be given a unique name conforming to the function name in the source documentation or its characteristics.

- The function name shall be succinct. This increases the ability of the reader to retain the idea being expressed, especially for large or complex systems consisting of many functions.

- The function name shall not imply any preference for a design solution, even if the source documentation specifies design detail.

Recommended

- The following function naming constructs are recommended. The use of the subject constructs should be restricted to instances where the verb constructs can not be derived:

CONSTRUCT	EXAMPLE
Verb	Boost
Verb Object*	Boost Vehicle Boost Launch Vehicle Display Fail at Ground Control Read Manual Signal into Logic Stream
Compound Verb	Recover and Evaluate

Compound Verb, Object*	Recover and Evaluate Vehicle Recover and Evaluate Launch Vehicle
Subject*	Evaluation Payload Evaluation
Compound Subject*	Recovery and Evaluation Vehicle Recovery and Evaluation Payload and Vehicle Recovery and Evaluation

* with or without modifiers, such as adjectives and/or prepositional phrases.

- The function name should be limited to 50 characters or less, including blank characters (spaces) between words in the function name.

- Abbreviations which are defined and maintained throughout the requirements engineering activities may be used in the function name.

As each function is identified and named, the primary and secondary references to the source documentation shall be maintained (BLOCK 13). Each function shall be supplemented by a description of the function and its purpose, a statement of the conditions under which the function is activated, and a description of the system external and internal inputs/ outputs that the function will receive, use, or generate. The latter descriptions serve as a basis upon which the requirements engineering activities of BLOCKS 7, 9, and 10 will proceed.

4.4.1 Conceptual Phase

Prior to development of the initial system specification (Type A), the functional requirements of the system are not usually collectively defined. The analysis team shall identify the functional requirements from available source documentation and through interviews with the using agency. If an initial system specification has been prepared, the analysis team shall evaluate the functions directly from the initial system specification and the supporting documentation as described in BLOCK 1. If the source documentation is evaluated to have justifiable and well defined functions, the analysis team shall consider adopting the functional identification. The analysis team shall not be restricted to the specific function names identified in the source documentation primarily because many source documents tend to identify functional requirements in design or solution terms.

4.4.2 Validation Phase

During the Validation Phase the initial system specification (Type A) shall be analyzed and authenticated. In addition, various end-item development (Type B) specifications shall be produced (BLOCK 12). The identification of system functions leading to the authentification of the system specification shall proceed under the same guidance as described above for the Conceptual Phase. Development specifications (Type B5s) are initiated from the baselined requirements as documented in the authenticated system specification. Functional requirements in the authenticated system specification are further analyzed and refined. The analysis of system requirements leading to the Type B5 specification generation (BLOCK 12) shall be oriented toward allocating system functions identified in the authenticated system specification to specific CPCIs. As such, the allocation shall be accomplished without specific solution orientations implied by the CPCI names or the function names below the CPCI.

4.5 Organize Functions into a Hierarchical Structure (BLOCK 4)

In conjunction with identifying the system functions as described in BLOCK 3, the functions shall be arranged into logical hierarchical structures (Figure 2). This form of organization is suited for structuring system functional requirements in a logical arrangement for communicating system functions and the relationships between the functions to design engineers. This form of organization provides a view of the system as an aggregate of functions broken down into a logical arrangement of subordinate discrete activities which must be performed. This logical form of organization is distinguished from the control-flow (BLOCK 9) and information-flow (BLOCK 10) forms of organizing system functions.

The functions of the system shall be grouped into higher levels of organization representing the first possible breakout of the system. Upper-level functions shall be refined by the identification of subordinate levels. Each level of the hierarchy shall be limited to six functions or less. This limit of six functions has been shown to increase the human understanding of the system functional requirements. Should the need exist for more than six functions at a given level, the analysis team shall restructure upper levels of the hierarchical structure to resolve the problem. In a functional hierarchy the sum of the activities of the functions on a given level shall be equal to the activity at the next higher level in the hierarchy. This principle means the total system activities are defined by the functions at the lowest level in the hierarchy.

During the course of the organization of functions into a logical hierarchy, the names of previously defined functions may be altered in order to conform to the logical structuring. On the other hand, the logical structuring may necessitate the creation of pseudo-function names in order to provide a means of organizing functions under special and meaningful groupings. In addition, the hierarchical structuring may necessitate identification or creation of new functions which were omitted in the source documentation.

4.5.1 Conceptual Phase

In developing the (Type A) system specification, the upper-levels of the system functional hierarchy shall be limited to groupings which communicate system operational needs. Many system developments require that the system functions be organized into discrete segments. In this case, the system becomes the first level of the functional hierarchy and the segment become becomes the next lower level.

System functions are organized into discrete segments when the system will require the participation of several contractors and government agencies. The groupings of system functions into segments shall be accomplished only for the specific purpose of clearly defining the contractual responsibilities between the procuring agency and the contractor(s). If this is the case, the system specification functional requirements shall be allocated to various segmented specifications. Therefore, the first level breakout of the hierarchy shall represent the segment. If the allocation is justifiable (because of predetermined contractual reasons), the analysis team shall incorporate the segment organization into the second level of the system hierarchical breakout. If the segmentation is not predetermined and binding, the analysis team may restructure the segments identified in the source documentation when further analysis of the functions justifies different segmentation and lower-level functional breakdowns.

The next level (with or without segmenting) is the functional area (MIL-STD-480, 483 (USAF), and 490). An example of discrete top-level functions at a functional area level in the hierarchy for an electronic system might be surveillance, tracking, identification, interceptor control, and communications. The analysis team shall continue defining and expanding the system functional requirements into a logical organization of subordinate functions; each level shall be limited to six functions or less.

4.5.2 Validation Phase

The hierarchical organization of functions into segments and functional areas shall proceed under the same guidance as described above for the Conceptual Phase. The functions of the system specifications (or segmented specification) are further allocated to various end-items. In conjunction with this allocation, the next level below the functional area in the functional hierarchy is defined, the configuration item (CI), or in the case of Type B5 specification preparation, the Computer Program Configuration Item (CPCI).

Below the CPCI, the hierarchical structure consists of functions and any number of subordinate functions. Naturally, the definition of some branches of the hierarchy will proceed more rapidly and to a greater number of levels than others. Areas needing more study shall be identified and the structure shall be completed when conclusions resulting from the studies are available. The functional hierarchical structure shall include all the system functions.

During the course of defining, analyzing, and allocating system requirements, the analysis team shall evaluate and be guided by existing design studies and other analyses of system logistic support, system maintenance, system activation and test, and personnel and training. The functional allocation shall identify specific problem areas (i.e., technical, logistical, financial) where additional studies will be required before the allocation can proceed or be validated. All allocations shall be based upon sound engineering reasoning, since the allocation of system functions to specific physical end-items is a major system design decision. Although this allocation may be predetermined by such considerations as policy, economics, or existing system characteristics, it is essential that the analysis team review all allocations thoroughly in order to validate the technical integrity of the resulting system. Primary and secondary references to source documentation (studies, technical papers, etc.) supporting the justification of the organization of the functional hierarchy shall be maintained (BLOCK 13).

4.6 Identify System Constraints (BLOCK 5)

In conjunction with the identification of system functions and organizing functions into a hierarchical structure, the analysis team shall identify all system constraints. The constraint requirements shall be limited to performance, physical, operability and design. Test Requirement constraints are addressed under BLOCK 11. Constraint requirements shall be derived from available source documentation or from the results of trade-off studies, feasibility studies or advanced development studies. Each constraint requirement shall be related to specific function levels in the functional hierarchy. A constraint applied to a given level in the functional hierarchy implies that the constraint is applicable to each lower level function in the hierarchy. As the constraint analysis continues the constraints may be allocated to lower level functions in the functional hierarchy. Constraints which are not clearly justified from available documentation shall be eliminated from consideration until documented justification is available. All constraint requirements shall be stated in specific quantifiable parameters, either as a single value or range of values, including the unit of measure, limits, accuracy or precision, and frequency.

During the course of identifying the various constraints imposed on the functions of the system, the analysis team shall verify that no combination of constraints results in excessive or unrealistic engineering requirements (BLOCK 14). Technical risks identified by the analysis of constraints shall be followed up by additional studies to resolve areas of conflict.

Primary and secondary references to source documentation and analysis and studies which support and justify each constraint requirement shall be maintained (BLOCK 13).

4.6.1 Conceptual Phase

During the Conceptual Phase the analysis team shall identify the constraint requirements at the upper levels of the functional hierarchy, namely at the system (or segment) level and functional area level. Detailing of constraints below these first two levels shall be avoided unless specific substantiated reasons exist to address constraints at lower levels in the functional hierarchy. Over specifying constraints during initial system specification development limits the design flexibility during later phases of the system acquisition life cycle. The constraint requirements will vary with the available source documentation and the quality of engineering studies accomplished during the Conceptual Phase. System capacities and accuracies for a surveillance system might include the maximum number of intercepts, tracks, and sensors. Functions associated with information processing might include requirements for handling a specific number of messages of a particular size, and at specific frequencies.

The analysis team shall minimize constraints to requirements which can be tested (BLOCK 11). Constraints which are high development risks or which may conflict with other constraint requirements shall be examined in subsequent Conceptual Phase or Validation Phase studies to clarify possible conflicts and reduce technical, logistical and financial risks.

4.6.2 Validation Phase

The criteria described above for the Conceptual Phase shall apply. The analysis team shall eliminate all constraints which are not justified and testable from the system specification or supporting studies and analysis as part of authenticating the requirements. In the preparation of the computer program development specification (B5) requirements, the allocation of constraints shall be extended to the CPCI as well as the CPCI subordinate functions. All allocations shall result from system engineering decisions based upon development studies. The analysis team shall determine the need for additional studies to verify that the constraint requirements are realistic and within the state-of-the-art. Specific solutions to technical problems resulting from Conceptual or Validation Phase studies shall be omitted from development specification requirements (BLOCK 12). The study results shall be used only to determine that constraint requirements are realistic and testable.

4.7 Identify System Using Activities (BLOCK 6)

Using activities (organizations, operational units, or operator positions) which interact with the system shall be identified. The identification of using activities provides the basis of information-flow analysis (BLOCK 10). The identification shall include the names of using organizations identified in the source documentation or through other determinations such as human engineering studies. Lower level position names, such as specific operator positions shall be identified and described to the level of detail required for the associated functions.

Using activities are a form of design constraint but are separately presented in this guidebook in order to support other requirements engineering activities such as information-flow analysis (BLOCK 10). Whenever using activities are identified, there must be sufficient justification, such as engineering analysis, which clearly shows that the using activity is necessary and represents an absolute requirement and not just a desirable feature.

4.7.1 Conceptual Phase

The organizations, operational units, and positions during the Conceptual Phase shall be described for the upper levels of the functional hierarchy and shall concentrate upon describing the interaction of the using activities with the system as a whole. The specific names of the organization, operational units, and positions shall be determined from the source documentation, interviews with the using activity, and through associated studies and analyses, i.e. human engineering studies and man-machine task analysis. The personnel position descriptions shall include the duties of personnel, and the numbers to operate, maintain and control the system.

4.7.2 Validation Phase

During the Validation Phase the organizations, operational units, and positions shall be further refined and allocated to lower level functions, i.e. CPCIs and functions below the CPCI. Human performance requirements relative to the specific positions shall be considered as constraints upon the associated functions. For instance, minimum response times for human decision making, maximum time for response, etc., shall be identified. Subsequently, BLOCK 5 shall be repeated to define the human factor constraints and associate them with the proper functions.

4.8 Identify External System Inputs-Outputs (BLOCK 7)

In conjunction with identifying the using activities, the analysis team shall identify the output (responses) required from the system. Output information consists of system messages and reports necessary for the operation, maintenance, control of the system and support of the mission objectives.

Subsequent to each output being defined, the associated system inputs (stimuli) shall be identified. The input information may be used directly from the external source or used by the system (see BLOCK 10) to derive all or part of an output. Inputs and outputs shall be associated with their respective sources or destinations. These sources and destinations may be the using activities or external systems. Additional informational requirements, such as internal information necessary for the system's operation, shall be identified during BLOCK 10.

Each input or output (I/O) shall be given a unique name conforming to the I/O name in the source documentation or its characteristics. The I/O naming convention shall be consistent throughout the requirements engineering process and shall be defined during the requirements engineering planning activities (BLOCK 2). Parts of an input or output shall be identified and named as the requirements engineering process continues. Primary and secondary references to source documentation and analysis and studies which identifies the need for the I/O shall be maintained (BLOCK 13). Each I/O shall be supplemented by a description of the I/O and its purpose.

4.8.1 Conceptual Phase

The inputs and outputs defined during the Conceptual Phase shall concentrate upon the upper levels of the functional hierarchy. The emphasis shall be upon identifying specific output requirements necessary for the operational use of the system to achieve mission objectives. Output message formats shall be specified to a level which can support additional analysis of information processing resource requirements during the Validation Phase. Specific outputs such as message formats shall be described by type, format or size, and frequency. The level of detail may vary according to the system or system segment being defined. Early in the definition it may only be possible to define the existence or general nature of the outputs and inputs. Inputs and outputs to other systems or system segments shall be precisely defined.

4.8.2 Validation Phase

During the Validation Phase the outputs and inputs described in the authenticated system specification shall be expanded and refined if not completed during the Conceptual Phase. As a result of sizing and timing estimates, the output and input requirements shall be associated with specific CPCIs and functions below the CPCI. Quantitative parameters shall be described for all inputs and outputs including units of measure, accuracy, the precision requirements, and frequency. All I/O must be defined completely by the end of the Validation Phase.

4.9 Structure System Inputs-Outputs (BLOCK 8)

Concurrent with BLOCK 6 and 7 activities, the system inputs and outputs (I/O) shall be arranged into hiearchical structures (Figure 3). The emphasis on the I/O hierarchical structures is to organize the I/O and their subordinate parts into logical organizations or simply as groupings of information. Structuring the I/O is an effective means of identifying incomplete or missing I/O requirements and for communicating the input and output requirements to design engineers.

Parts of I/O identified during BLOCK 7 shall be associated with other I/O and organized into hierarchical structures. Changes and additions to the I/O hierarchical structures may be required as information-flow analysis (BLOCK 10) is accomplished. The upper parts of the individual I/O hierarchical structures shall be equivalent to the aggregate of the subordinate parts in the hierarchy. During the course of organizing the I/O into a hierarchy, the names of previously defined I/O may be altered in order to conform to the logical information structure being defined. On the other hand, the hierarchical structuring may necessitate the creation of pseudo input/output names in order to provide an effective means of organizing the I/O hierarchical structures in special and meaningful groupings. In addition, the hierarchical structuring may necessitate the identification or creation of new I/O requirements which were omitted during earlier requirements engineering activities or from the source documentation.

4.10 Perform Control-Flow Analysis (BLOCK 9)

After the functions of the system are identified (BLOCK 3), the control flow between the functions shall be described in control-flow diagrams. Control-flow analysis provides a means of viewing the system from an activity-oriented perspective and is often referred to as functional-flow analysis. The control-flow diagrams (Figure 4) shall describe the sequential flow between system functions. The control-flow diagrams shall indicate only the relationship between system functions and shall not imply any lapse in time or intermediate activity. Conditions which determine the flow directions shall be described using the following control-flow relationships as illustrated in Figure 4:

SERIES This is a sequential relationship between two or more activities. This relationship is assumed unless an AND, OR, or UTILIZE relationship is indicated in the flow path.

AND Activities preceding the AND must be accomplished before the flow may continue.

OR Any one of the alternate paths may lead to the next activity. The conditions upon which the alternate paths are selected are associated with the OR.

UTILIZES This relationship indicates that a function on a path is dependent upon the use of one or more other functions in order to accomplish its activities. A single function or sequence of functions may be defined once and utilized as frequently as necessary in the control flow without having to be redefined (replicated) for each use.

The control flow shall be restricted to concepts backed by system engineering studies or the like which clearly resolve any uncertainty of technical risks associated with the flow concept described. Where uncertainty exists the relationships shall be described as tentative or not completed, as appropriate, until subsequent analysis resolves the uncertainty. As the control flow is identified, the primary and secondary references to the source documentation shall be maintained (BLOCK 13).

Control-flow analysis will necessitate changes and additions to previously defined functions, constraints, and I/O, as well as the hierarchy structures and other previously defined relationships. Missing or incomplete requirements shall be determined and the deficiencies shall be corrected.

4.10.1 Conceptual Phase

During the Conceptual Phase the control-flow analysis shall be concentrated upon describing the sequential flow (SERIES) between the functions of the system. Conditions (AND, OR, UTILIZES) which determine the flow direction shall be described when appropriate to the Conceptual Phase analyses performed. If an initial system specification has been prepared, the analysis team shall evaluate the control-flow relationships contained in the initial system specification and the other supporting documentation. The control flow at the upper levels of the functional hierarchy shall be addressed initially. As the functional hierarchy evolves, analysis of the control relationships allocated to lower level functions shall be accomplished. As a result, the control-flow relationships shall be described for all lower level functions identified during the Conceptual Phase. The uncertainties in the control flow which are not resolved in the Conceptual Phase shall be resolved during the Validation Phase.

4.10.2 Validation Phase

The control-flow relationships in the system specification developed during the Conceptual Phase are further analyzed and refined during the Validation Phase. The control-flow analysis leading to the authenticated system specification shall proceed under the same guidance as described above for the Conceptual Phase. Control-flow analysis shall continue from the baselined requirements as documented in the authenticated system specification. The control-flow relationships in the authenticated system specification are further analyzed and refined. The Type B5 control-flow analysis shall be oriented toward defining the control flow between CPCIs and between functions within CPCIs. The control-flow description shall be expanded as the system functional hierarchy evolves. The Validation Phase control-flow description shall include all four conditions (SERIES, AND, OR, UTILIZES) which determine the flow direction as appropriate. All control-flow relationships shall be completed by the end of the Validation Phase.

4.11 Perform Information-Flow Analysis (BLOCK 10)

This activity builds upon the I/O hierarchical structure (BLOCK 8) by providing a means of analyzing the system as an information processing system (Figure 5). During this analysis, the flow relationships between external system inputs and resulting outputs shall be identified in information-flow diagrams. These diagrams provide the basis for determining that each I/O is used, derived, or updated. An effective means of information-flow analysis is to trace an output back to the system input: external data, messages, or stimuli. This method permits the relationships between associated functions and the internal information necessary to support the derivation of the output to be identified. The flow associations between system information shall be described using the following information-flow relationships as illustrated in Figure 5:

USES — This relationship indicates that a function on the path uses external information (external input) or internal system information (internal input) in order to accomplish its activities.

DERIVES — This relationship indicates that a function on the path derives either external information (external output) or internal system information (internal output) as part of its activities.

UPDATES — This relationship indicates that a function on the path updates internal system information as part of its activities.

The information flow shall indicate the relationship between system functions and system information (external and internal system I/O) and shall not imply any lapse in time or intermediate I/O being used, derived, or updated. These relationships shall be identified for each level in the information hierarchy. As the information analysis continues the relationships shall be allocated to lower levels in the information hierarchy as the I/O is identified (BLOCK 7) and structured (BLOCK 8).

For the purpose of information-flow analysis, the using activities identified during BLOCK 6 are integral to the definition of the system as an aggregate of hardware, computer programs, personnel, facilities, and procedural data. The relationships between the using activities shall be described using the following information-flow relationships as illustrated in Figure 5:

PROVIDES This relationship indicates that a using activity is the source of the external input.

RECEIVES This relationship indicates that a using activity is the recipient of the external output.

The information flow shall be restricted to concepts backed by system engineering studies or the like which clearly resolve any uncertainty or technical risks associated with the flow concept described. Where uncertainty exists the relationships shall be described as tentative or not completed as appropriate until subsequent analysis resolves the uncertainty. As the information flow is identified, the primary and secondary references to the source documentation shall be maintained (BLOCK 13).

Information-flow analysis will necessitate changes and additions to previously defined functions, constraints, and I/O as well as the hierarchy structures and other previously defined relationships. Missing or incomplete requirements shall be determined and the deficiencies shall be corrected.

4.11.1 Conceptual Phase

During the Conceptual Phase the information-flow analysis shall be concentrated upon describing the information flow between system internal and external I/O and associated functions (PROVIDES, RECEIVES). Other information-flow relationships (USES, DERIVES, UPDATES) which describe the system internal information flow shall be described when appropriate to the Conceptual Phase analyses performed. If an initial system specification has been prepared, the analysis team shall evaluate the information-flow relationships contained in the initial system specification and other supporting documentation. The information flow at the uper levels of the information hierarchy shall be addressed initially. As the information hierarchy evolves, the information-flow relationships shall be allocated to appropriate lower levels in the information hierarchy. As a result, the information-flow relationships shall be described for all lower level internal and external I/O and associated functions identified during the Conceptual Phase. The uncertainties in the information flow which are not resolved in the Conceptual Phase shall be resolved during the Validation Phase.

4.11.2 Validation Phase

The information-flow relationships in the system specification developed during the Conceptual Phase are further analyzed and refined during the Validation Phase. The information-flow analysis leading to the authenticated system specification shall proceed under the same guidance as described above for the Conceptual Phase. The Type B5 information-flow analysis shall continue from the baselined requirements as documented in the authenticated system specification. The information-flow relationships in the authenticated system specification are further analyzed and refined. The information-flow analysis leading to Type B5 specification generation (BLOCK 12) shall be oriented toward defining the information flow between CPCIs and functions within CPCIs. The information-flow description shall be expanded as the system information hierarchy evolves. All information-flow relationships shall be completed by the end of the Validation Phase.

4.12 Perform Test Analysis (BLOCK 11)

Test requirements identify the system requirements which will be evaluated during system integration and test. The principle objective of test analysis is to identify which areas in the system definition shall undergo formal test and verification. This is achieved by identifying test points on the control-flow and information-flow paths (Figures 4 and 5). As the control flows and information flows evolve, the analysis team shall determine test points on the flow paths. These test points shall be added to the flow paths at the selected test data sampling locations. The selection of test points shall be accomplished concurrent with the test planning activities. As test cases are determined by analysis of the control and information flows, the test points shall be described and associated with test plans and procedures.

The association between system test plans, analyses, and studies documented prior to, during, and subsequent to the start of formal requirements engineering is crucial to the overall requirements engineering concept. Documented test objectives preceding formal requirements engineering shall be analyzed. As a result, test points in the control and information flows shall be selected which provide data for various test cases which support testing objectives. Test analysis will necessitate changes and additions to previously defined system requirements definitions (functions, constraints, I/O, hierarchy structures, control and information flows, and associated relationships) in order to satisfy test objectives. Primary and secondary references shall be maintained between the test points and associated test plans and other supporting documentation (BLOCK 13).

4.12.1 Conceptual Phase

Before the development of the initial system specification, test objectives may be identified in various early planning documents, analyses, and studies. Concurrent with the development of the initial system specification the Test and Evaluation Master Plan (TEMP) is prepared. The TEMP documents the overall test philosophy, testing concepts, subsystem and system test objectives, and the basic test planning information. The TEMP and the quality assurance section of the system specification (MIL-STD-490/483 (USAF), Type A, System/Segment Specification) are the principle test planning requirements developed during the Conceptual Phase.

Prior to the development of the initial system specification and TEMP, the analysis team shall analyze the test objectives which are stated in various planning documents, analyses, and studies. Test points shall be determined and associated with Conceptual Phase control flows and information flows. The resulting analyses and test point determinations may require changes to the requirements definition as previously described. The preparation of the initial system specification quality assurance provisions (BLOCK 12) and TEMP shall proceed from the test point determinations and analysis activities performed during the Conceptual Phase test analysis.

If an initial system specification and TEMP have been prepared, the analysis team shall evaluate the test objectives and requirements of these additional documents along with associated early planning documents, analyses, and studies. As the test points and test cases are determined the quality assurance provisions of the system specification may require clarification and refinement. Subsequent to the authentification of the system specification, the quality assurance provisions shall be required and therefore reflected in the contractor test plans and procedures.

4.12.2 Validation Phase

Test points in the system specification developed during the Conceptual Phase shall be further analyzed and refined as the control and information flows evolve during the Validation Phase. The test analysis leading to the authenticated system specification shall proceed under the same guidance as described above for the Conceptual Phase. Validation Phase test analysis leading to the generation of development specifications (Type B5s) shall be based upon Conceptual Phase test analyses. The Conceptual Phase test points shall be further refined and allocated to Validation Phase control and information flows. If test points were not identified during the Conceptual Phase activities, the analysis team shall identify test points for Validation Phase control and information flows in the same manner as described for the Conceptual Phase. The test points shall continue to be refined as the control and information flows evolve during the Validation Phase. All test points shall be described by the conclusion of the Validation Phase and integrated into the evolving quality assurance section of development specifications (MIL-STD-490/483 (USAF), Type B5) and associated test plans and procedures.

4.13 Prepare Specification Documentation (BLOCK 12)

The preparation of specification documents shall be accomplished in accordance with MIL-STD-490 as supplemented by MIL-STD-483 (USAF). Specifications serve to document the system requirements throughout the system acquisition life cycle. In Air Force acquisitions these documents are an integral part of the management concept: configuration management, data management, system integration and testing, and contracting.

The system requirements definition and analysis activities (BLOCKS 3-11) provide the basis upon which the preparation of specification documents shall proceed. The products of BLOCKS 3-11 (functional hierarchical structures, I/O hierarchical structures, control flows, information flows, etc.) shall be incorporated directly into the specification documents in accordance with the prescribed format of MIL-STD-490/483. Additional specification document inputs (text, etc.) may be required to complete the document, however, the additions shall not conflict with the requirements engineering products previously produced. All requirements in the specification documents shall be traceable to the products of the requirements engineering performed as described in BLOCKS 3-11. Therefore, each specification document shall be cross-referenced to the requirements engineering products (BLOCKS 3-11).

Where the specification document paragraphs require additional text to satisfy MIL-STD-490/483 (USAF) specification preparation requirements, the text shall be direct and succinct. The text shall be free of vague and ambiguous terms. The text shall use the simplest words and phrases which convey the intended meaning. System requirements shall be complete, whether by direct statements or references to other documents, such as the requirements engineering products (BLOCKS 3-11) or other documents as identified and maintained (BLOCK 13). Consistency in terminology and the organization of material will contribute to the specification document's clarity and usefulness. The intent of the text is to provide supplemental understanding of the requirements identified and analyzed previously. As such the style of writing shall emphasize short and concise sentence structure. Well-written sentences shall be required with a minimum of punctuation. Punctuation shall be used to aid reading and prevent misunderstandings. When extensive punctuation is required for clarity, the sentence shall be restructured to eliminate the deficiency. The emphasis shall be upon short and concise sentences and the elimination of compound clauses. Additional style, format and general instructions for preparation of specification documents shall be accomplished as described in MIL-STD-490, paragraph 3.2.

Care shall be taken to ensure that the supplemental text statements do not conflict with previously defined system requirements (BLOCKS 3-11). Where conflicts arise, the previous requirements definitions and analysis shall take precedence, the conflicts in the supplemental text shall be removed. Reaccomplishing previous tasks (BLOCKS 3-11) may be necessary where conflicts indicate deficiencies in products developed during earlier system definition and analysis. The notes section of each specification document (Section 6, Notes) shall be used for background information or rationale which may be of assistance in understanding the requirements or specification itself.

4.13.1 Conceptual Phase

Air Force System Specifications are prepared in accordance with MIL-STD-490, Appendix I (Type A, System Specification) as supplemented by MIL-STD-483 (USAF), Appendix III (System Specification/System Segment Specification). If the requirements engineering activities (BLOCKS 1-11) have been accomplished prior to the development of an initial system specification, the initial system specification shall be developed as described in 4.13.

If an initial system specification has been prepared, the requirements engineering activities (BLOCKS 1-11) shall be accomplished and a new system specification shall be prepared as described in 4.13. The resulting system specification shall be the basis upon which the Validation Phase is initiated. Table 2 provides a cross reference between the requirements engineering activities described in this guidebook and the associated paragraph requirements in MIL-STD-490/483 (USAF) for Type A, System Specifications.

4.13.2 Validation Phase

If an initial system specification has been prepared but has not been authenticated, the requirements engineering activities shall be accomplished (BLOCKS 3-11) and a new system specification shall be generated as described in 4.13. The new generated system specification may become the authenticated system specification if contractually required by the procuring activity. Again, Table 2 provides a cross reference between the requirements engineering activities described in this standard and the associated paragraph requirements in MIL-STD-490/483 (USAF) for Type A, System Specifications. The preparation of Computer Program Development Specifications during the Validation Phase shall be done in accordance with MIL-STD-490, Appendix VI (Type B5, Computer Program Development Specification) as supplemented by MIL-STD-483 (USAF), Appendix VI (Type B5, Computer Program Configuration Item Specification). Table 3 provides a cross reference between the requirements engineering activities described in this guidebook and the associated paragraph requirements in MIL-STD-490/483 (USAF) appendices for Type B5 specification preparation.

4.14 Perform Traceability Analysis (BLOCK 13)

System requirements traceability is another effective means of identifying incomplete or missing requirements. Traceability gives the analyst a means of verifying the requirements by linking each requirement to the varying forms of source documentation such as program directives and plans, studies, analyses, test plans, associated specifications (Type A, B, etc.) and the

Table 2. Cross Reference between System Specification (Type A) Documentation and Requirements Engineering Activities

MIL-STD-490/483 (USAF) Paragraphs			Requirements Engineering Activities (BLOCKS)
Section 1.	Scope		
Section 2.	Applicable Documents		1,13
Section 3.	Requirements		
	3.1	System Definition	3,4
	3.1.1	General Description	4
	3.1.2	Missions	3-10
	3.1.3	Threat	
	3.1.4	System Diagrams	4,9,11
	3.1.5	Interface Definition	3-10
	3.1.6	Government Furnished Property List	5
	3.1.7	Operational and Organizational Concepts	6
	3.2	Characteristics	
	3.2.1	Performance Characteristics	5
	3.2.2	Physical Characteristics	5
	3.2.3	Reliability	5
	3.2.4	Maintainability	5
	3.2.5	Availability	5
	3.2.6	System Effectiveness Models	5
	3.2.7	Environmental Conditions	5
	3.2.8	Nuclear Control Requirements	5
	3.3	Design and Construction	5
	3.3.1	Materials, Processes, and Parts	5
	3.3.2	Electromagnetic Radiation	5
	3.3.3	Nameplates and Product Markings	5
	3.3.4	Workmanship	5
	3.3.5	Interchangeability	5
	3.3.6	Safety	5
	3.3.7	Human Performance/Human Engineering	5
	3.3.8	Computer Programming	5
	3.4	Documentation	1,13
	3.5	Logistics	
	3.5.1	Maintenance	5
	3.5.2	Supply	5
	3.5.3	Facility and Facility Equipment	5
	3.6	Personnel and Training	
	3.6.1	Personnel	5
	3.6.2	Training	5
	3.7	Functional Area Characteristics	3-10
	3.8	Precedence	3-10
Section 4.	Quality Assurance Provisions		11,13
	4.1	General	11,13
	4.1.1	Responsibility for Tests	11,13
	4.1.2	Special Tests and Examinations	11,13
	4.2	Quality Conformance Inspections	11,13
Section 5.	Preparation for Delivery		5
Section 6.	Notes		1,3-11,13
Section 10.	Appendices		1,3-11,13

Table 3. Cross Reference between Computer Program Development Specification (Type B5) Documentation and Requirements Engineering Activities

	MIL-STD-490/483 (USAF) Paragraphs		Requirements Engineering Activities (BLOCKS)
Section 1.	Scope		
	1.1	Identification	
	1.2	Functional Summary	3
Section 2.	Applicable Documents		1,13
Section 3.	Requirements		
	3.1	Computer Program Definition	
	3.1.1	Interface Requirements	3-10
	3.1.1.1	Interface Block Diagram	3-10
	3.1.1.2	Detailed Interface Definition	3-10
	3.2	Detailed Functional Requirements	3,4,9,11
	3.2X	Function X	3,4,9
	3.2.X.1	Inputs	6,7,8,9,10
	3.2.X.2	Processing	3,4,5,9
	3.2.X.3	Outputs	6,7,8,9,10
	3.2.n	Special Requirements	5,11
	3.2.n.1	Human Performance	5
	3.2.n.2	Government-Furnished Property List	5
	3.3	Adaptation	6,7,8,10
	3.3.1	General Environment	5
	3.3.2	System Parameters	5
	3.3.3	System Capacities	5
Section 4.	Quality Assurance Provisions		
	4.1	Introduction	11
	4.1.1	Category I Test	11
	4.1.2	Computer Programming Test and Evaluation	11
	4.1.3	Preliminary Qualification Tests	11
	4.1.4	Formal Qualification Tests	11
	4.1.5	Category II System Test Program	11
	4.2	Test Requirements	11
	4.3	Acceptance Test Requirements	11
Section 5.	Preparation for Delivery		5
Section 6.	Notes		1,3-11,13
Section 10.	Appendices		1,3-11,13

like. Throughout the requirements engineering activities the need exists for the analyst to be able to evaluate the impact of changes and additions to the requirements. Whatever the reason (policy, economics, study or analysis results, engineering change proposals, etc.) traceability provides the capability to readily identify associated impacts to the system definition as well as to trace the impacts to all other associated documentation. Requirement change impacts can be readily analyzed and the appropriate actions taken. The trace links to associated plans, analyses, studies, and specifications accomplished prior to, during, and subsequent to the start of formal requirements engineering are crucial to the integrity of the requirements definition process.

Throughout the requirements engineering activities (BLOCKS 3-11), each requirement shall be associated with the sources of the requirement (source documents). These source references shall relate the system requirements to all associated specifications, studies, analyses, plans, Types A, B, and C specifications, program management directives and plans, system sizing and timing studies, prototyping, simulations, test planning, and the like. Two forms of references shall be provided: primary and secondary source references. Primary source references refer to specific paragraphs in source documentation which are the origin of the requirement. Secondary source references refer to specific paragraphs in the source documentation which provide information about closely related requirements, discussions of the rationale about the requirement or other useful background information.

4.15 Perform Consistency and Completeness Analysis (BLOCK 14)

Throughout the requirements engineering activities (BLOCKS 3-13) analysis of the consistency and completeness of the requirements definition assures the integrity of the system being defined. Associated with each requirements engineering activity are various consistency and completeness checks which shall be performed concurrent with each block:

4.15.1 Identify System Functions: Block 3

- Are all functions defined in operational terms as opposed to solution oriented terminology such as data processing terms? Remove or rename all functions which imply "how-to".

- Are the functions backed by studies or the like which resolve technical risks? Remove all functions which are not feasible or analyze the risks and resolve any uncertainty.

- Are all source references identified for each function?

- Have high level functions been broken down into lower level functions?

- Can any functions be consolidated? Can duplicated or similar functions be eliminated or consolidated?

4.15.2 Organize Functions into a Hierarchical Structure: Block 4

- Does the hierarchical structure contain all functions defined?

- Have all source references supporting the functional hierarchy been identified?

- Does the sum of the activities of each group of lower level functions represent the activities of the function at the next higher level in the functional hierarchy? Are there any missing lower level functions?

- Does each level of the functional hierarchy structure consist of six functions or less? If not, restructure the hierarchy.

- Does the hierarchy of functions contain all supporting functions which are necessary for the operation of the system?

4.15.3 Identify System Constraints: Block 5

- Have all constraints been associated with specific function levels in the functional hierarchy?

- Do constraints have source documentation references? Each constraint shall be backed by documentation which provides the rationale, or feasibility for the constraint. If no source reference is identified or available the constraint shall be eliminated.

- Do any combinations of constraint requirements imposed on the functions result in excessive or unrealistic engineering requirements, thereby increasing costs technical and schedule risks during the acquisition life cycle? Where uncertainty or conflicts exist, further analysis shall be performed. As a result the conflicts shall be removed by eliminating or adjusting the conflicting requirements.

- Is each constraint requirement defined in quantifiable terms: single values or range of values, including units of measure, limits, accuracy or precision, and frequency?

- Have constraints been overspecified? Excessive constraints eliminate design flexibility.

- Are constraint requirements applied to the appropriate functions?

4.15.4 Identify System Using Activities: Block 6

- Have all using activities (organizations, operational units, or positions) been identified and related to associated inputs and outputs?

- Have all using activity source references been identified?

4.15.5 Identify External System Inputs-Outputs: Block 7

- Have all external system Inputs and Outputs been identified?

- Have all required external I/O formats (messages, etc.) been identified?

- Are all external I/O associated with using activities (BLOCK 6) and functions (BLOCK 10)?

- Are all external I/O source document references identified?

4.15.6 Structure System Inputs-Outputs: Block 8

- Does the information hierarchy structure contain all I/O as described in the source documentation?

- Does the sum of the I/O at a given level represent the total contents of the I/O at the next higher level in the hierarchy?

- Do the I/O structures represent the contents of required messages, etc.?

4.15.7 Perform Control-Flow Analysis: Block 9

- Is there a control-flow sequence defined for every function?

- Is each control-flow sequence complete and logically correct? No lapse in time or intermediate activity shall be implied between functions in the control-flow sequence.

- Are all conditions which determine the flow direction described using the control-flow relationships (SERIES, AND, OR, and UTILIZE)?

- Are Conceptual Phase control flows primarily SERIES flows?

- Is each control-flow sequence referenced to source documentation which establishes the need and rationale for the control-flow sequence as well as resolves any uncertainty of technical risks?

- Are all control flows complete at the conclusion of the Validation Phase?

4.15.8 Perform Information-Flow Analysis: Block 10

- Is there an information-flow sequence defined for every external output desired? Can every external output be traced to inputs?

- Is every external input and output used?

- Is each information-flow sequence complete and logically correct? The information flow shall indicate only the relationship between system functions and system information (external and internal system I/O) and shall not imply any lapse in time or intermediate I/O being used, derived, or updated.

- Are all information-flow relationships (USES, DERIVES, UPDATES, PROVIDES, and RECEIVES) described as appropriate in each information-flow sequence?

- Are all using activities (BLOCK 6) associated with system external I/O?

- Is each information-flow sequence referenced to source documentation which establishes the need for the information-flow sequence as well as resolves any uncertainty or technical risks?

4.15.9 Perform Test Analysis: Block 11

- Are all test points identified?

- Are the test point source references (TEMP, Test Cases, Test Plans and Procedures, Quality Assurance Provisions of specifications, etc.) identified?

- Are test points allocated to control and information flows which are appropriate to the system definition being described, documented, and tested?

- Have all test points been identified at the conclusion of the Validation Phase?

4.15.10 Prepare Specification Documentation: Block 12

- Have all requirements defined during BLOCK 3-11 been incorporated into the appropriate specification paragraphs as described in Tables 2 and 3?

- Has supplemental text been restricted and concisely written as described in BLOCK 12?

- Has supplemental text been reviewed to identify any conflicts between the text and the system requirements defined in BLOCKS 3-11? Remove any conflicts in the text or reaccomplished analysis to resolve deficiencies.

4.15.11 Perform Traceability Analysis: Block 13

- Have all system requirements (functions, contraints, control and information flows, etc.) been associated with primary and secondary source reference?

- Have all system requirements which have no source references been eliminated?

APPENDIX A - GLOSSARY

This appendix consists of definitions of the major terms used throughout this document and concludes with a list of acronyms and abbreviations. The definitions are drawn from a variety of sources which are identified at the conclusion of the definition section.

DEFINITIONS

Acquisition Life Cycle - The five phases of system and related item acquisition (Conceptual, Validation, Full-Scale Development, Production and Deployment) with three key decision points (Program, Ratification, and Production Decisions) between each of the first four phases. A program may skip a phase, have program elements in any or all other phases, or have multiple decision points per phase. (AFR 800-2) [1] (See also System/ Acquisition Life Cycle). These phases are being redefined [12], [13].

And - Activities preceding the AND must be accomplished before the flow may continue.

Authenticate - The act of signifying (by the approval signature of a responsible person of the procuring activity) that the Government is in agreement with the requirements contained in the specification. Authentication by the procuring activity normally will be accomplished on that issue of the specification which is to be the contractual requirement for the baseline which that particular specification defines (MIL-STD-483 (USAF) paragraph 3.4.9). [2]

Availability - The degree to which the system shall be in an operable and committable state at the start of the mission(s) is called for at an unknown (random) point in time [3]. Reliability and Maintainability are interrelated. The formula used to express this relationship is:

$$A = \frac{MTBF}{MTBF\ \ MTTR}$$

where

A = Availability
MTBF = Mean Time Between Failure
MTTR = Mean Time to Repair

A figure of merit such as Availability is much more meaningful when applied to systems that operate continuously rather than the use of MTBF. [1] (See also Reliability and Maintainability)

Base Line - A configuration identification document or a set of such documents formally designated and fixed at a specific time during a CI's life cycle. Base lines, plus approved changes from those base lines, constitute the current configuration identification. For configuration management there are three base lines, as follows:

a. Functional Base line. The initial approved functional configuration identification.

b. Allocated Base line. The initial approved allocated configuration identification.

c. Product Base line. The initial approved or conditionally approved product configuration identification. (DOD Directive. 5010.19).[4]

Civil Engineering - This term refers to the Air Force civil engineering functions as they relate to the design, construction maintenance, and operation of facilities necessary to support the acquisition and operation of a system or a major modification program. The impact of the various technical functions on Air Force civil engineering functions must be considered throughout the process of developing and acquiring a supportable and cost-effective system. Civil engineering requirements are derived as a part of the systems engineering process (see AFM 86-1). (See also Engineering Management). [6]

Computer Program - The computer program as it pertains to configuration management is a configuration item defined as a deck of punched cards, magnetic or paper tapes, or other physical medium containing a sequence of instructions and data in a form suitable for insertion into a computer. Computer programs used for administrative purposes and those not associated with system/equipment managed by AFR 65-3 are controlled by AFR 300-2. (See definition under Software). [5]

Computer Program Component (CPC) - A CPC is a functionally or logically distinct part of a computer program configuration item (CPCI) distinguished for purposes of convenience in designing and specifying a complete CPCI as an assembly of subordinate elements. [5], [7]

Computer Program Configuration Item (CPCI) - The computer program as it pertains to configuration management is a configuration item. A CPCI is defined as a deck of punched cards, magnetic or paper tapes, or other physical medium containing a sequence of instructions and data in a form suitable for insertion into a computer. (See also Computer Program) [8]

Computer Program Development Plan (CPDP) - The CPDP is the plan which identifies the actions required to develop and deliver computer program configuration items and necessary support resources. It is prepared by the implementing command or,if the development effort is contracted, the plan may be prepared by the contractor and approved by the implementing command. (AFR 800-14, Vol II) [9]

Computer Program Development Specification - Also called Computer Program Configuration Item Specification, MIL-STD-483 (USAF), see Type B5.

Computer Program Life Cycle - The sequence of activities grouped into phases that characterize the typical process of software production and use. The phases are

Analysis Phase
Design Phase
Coding and Checkout Phase
Test and Integration Phase
Installation Phase
Operation and Support Phase

A particular computer program will undergo these phases at least once during the system acquisition life cycle, however, this may occur entirely in one phase of the system acquisition life cycle (e.g., a mission simulation computer program in the conceptual phase) or over several system acquisition phases (e.g., a mission application program developed over the validation, full-scale development and production phases). See AFR 800-14 Volume II, Section 2-8, for further discussion of the computer program life cycle in the system acquisition life cycle. [8]

Concept of Operations. A verbal or written statement, in broad outline, of a commander's assumptions or intent in regard to an operation or series of operations. The concept of operations frequently is embodied in campaign plans and operation plans, in the latter case particularly when the plan covers a series of connected operations to be carried out simultaneously or in succession. The concept is designed to give the overall picture of the operation. It is included primarily for additional clarity of purpose and is frequently referred to as commander's concept. (Source: JCS Pub. 1) [13].

Conceptual Phase - The initial period when the technical, military, and economic bases for acquisition programs are established through comprehensive studies and experimental hardware development and evaluation. The outputs are alternative concepts and their characteristics (estimated operational, schedule, procurement, costs, and support parameters) which serve as inputs to the Decision Coordinating Paper (DCP) on major systems, Program Memoranda (PM) on smaller systems/equipment, and to HQ USAF decision documents (Program Management Directives) for programs that do not require OSD decisions. (AFR 800-2) [1] (see also Acquisition Life Cycle

Configuration - The functional and/or physical characteristics of hardware/software as set forth in technical documentation and achieved in a product. (DOD Directive 5010.19) [4]

Configuration Control - The systematic evaluation, coordination, approval or disapproval, and implementation of all approved changes in the configuration of a CI after formal establishment of its configuration identification. (DOD Directive 5010.19) [4]

Configuration Item (CI) - An aggregation of hardware/computer programs of any of its discrete portions, which satisfies an end-use function and is designated by the Government for configuration management. CIs may vary widely in complexity, size and type, from an aircraft, electronic or ship system to a test meter or round of ammunition. During development and manufacture of the initial (prototype) production configuration, CIs are those specification items whose functions and performance parameters must be defined (specified) and controlled to achieve the overall end-use function and performance. Any item required for logistic support and designated for separate procurement is a configuration item. (AFR 65-3) [1] The third level in the functional hierarchical structure. (See also System Segment, Functional Area, and CPCI)

Configuration Management - A discipline applying technical and administrative direction and surveillance to (1) identify and document the functional and physical characteristics of a configuration item, (2) control changes to those characteristics, and (3) record and report change processing and implementation status. (DOD Directive 5010.19, AFR 65-3, AFR 800-3) [4],[6] (See also Engineering Management)

Constraints - Performance Requirements, Physical Requirements, Operability, Test Requirements, and Design Requirements.

Contractor - An individual, partnership, company, corporation, or association having a contract with the procuring activity for the design, development, design and manufacture, maintenance, modification or supply of items under the terms of a contract. A government activity performing any or all of the above actions is considered to be a contractor for configuration management purposes. [4]

Control Flow (also called Functional Flow) - The description of the logical flow in which the system functions are accomplished in order to control the system functions and satisfy the operational requirements. The control flow indicates only the relationship between system functions and does not imply any lapse in time or intermediate activity. Conditions which determine the flow directions are described using the control-flow relationships: SERIES, AND, OR, and UTILIZES.

Decision Coordinating Paper (DCP) - The principle document to record essential system program information for use in support of the Secretary of Defense/Secretary of the Air Force decision making process. A DCP intended for final approval by the Secretary of the Air Force is called an Air Force Decision Coordinating Paper (AFDCP). (Ref: AFR800-2) [13]

Deficiency - Operational need minus existing and planned capability. The degree of inability to successfully accomplish one or more mission tasks or functions required to achieve mission or mission area objectives. Deficiencies might arise from changing mission objectives, opposing threat systems, changes in the environment, obsolesence, or depreciation in current military assets. [13]

Dependability - Dependability addresses the issues of system survivability, vulnerability (S/V) and external electromagnetic interference. Survivability is the ability of the system to achieve its mission under the conditions of a man-made hostile environment. In addition the system may be required to operate under the conditions of interference from external electromagnetic sources (Electromagnetic compatibility) as well as operate under threat of possible electronic countermeasures (ECM) such as spoofing and jamming.

Deployment Phase - The period beginning with the user's acceptance of the first operational unit and extending until the system is phased out of the inventory. It overlaps the production phase. (AFR 800-2) [1]

DERIVES - This relationship indicates that a function on the path derives either external information (external output) or internal system information (internal output) as part of its activities. (See also Information Flow)

Design and Construction - Minimum or essential requirements that are not controlled by performance characteristics, interface requirements, or referenced documents shall be specified. They shall include appropriate design standards, requirements governing the use or selection of materials, parts and processes, interchangeability requirements, safety requirements, and the like. Requirements for materials to be used in the item or service covered by the specification shall be stated, except where it is more practicable to include the information in other paragraphs. Requirements of a general nature should be first, followed by specific requirements for the material. Definitive documents shall be referenced for the material when such documents cover materials of the required quality. [3]

Design Engineering - This function uses the technical information (requirements, goals, criteria, constraints, etc.) developed through the systems engineering process to develop detailed design approaches, design solutions, and the test procedures to prove these solutions. [6] (See also Engineering Management)

Design Requirements - The minimum or essential design and construction requirements which are not addressed by other constraint requirement types: performance, physical, operability, and test requirements. During the initial phases of systems requirements engineering, certain design and construction standards (see Design and Construction) may be specified directly or by reference to other specifications or standards. As the system development continues, engineering analysis and trade study results (as well as other engineering activities such as prototyping and simulations) may indicate the need for additional design constraints which are practicable and necessary for the system's operation and maintenance (O&M).

Development (Part I or Type B5) Specification - A document which specifies the requirements peculiar to the design, development, functional performance, test, and qualification of the configuration item. It establishes performance criteria and test criteria for which the program shall be designed/ developed [MIL-STD-483(USAF)]. [7] (See also Type B Specification and Specifications)

Development Test & Evaluation (DT&E) - That testing and evaluation of individual components, subsystems, and, in certain cases, the complete system, which is conducted predominantly by the contractor. [7]

Discrete Event Simulation - On the system level, a discrete event simulation may be utilized to support computer system studies. A discrete event simulation is one in which information blocks and computer program timing can be replicated allowing evaluation of throughput capability and identification of potential design problems. This type of simulation is used to check the software design for possible discrepancies that might cause the system to be saturated as a result of either information overloads or time responses that are slower than required. These studies provide estimates of computer sizing and timing for the processing requirements and they evaluate the real-time computational conflicts, including the effects of interrupts. [9] (see also functional simulation, Scientific Simulation, Engineering Simulation)

Electromagnetic Compatibility (EMC) - Defined as "the capability of an equipment, component, subsystem or system to operate in its operational electromagnetic environment at design levels of efficiency, without causing or suffering unacceptable degradation due to electromagnetic interference." The application of approved EMC standards in the development and procurement of equipment is required by AFR 80-23 (para 6d). [1] Where applicable, requirements pertaining to electromagnetic radiation shall be stated in terms of the environment which the item must accept and the environment which it generates. [3]

Electronic Warfare (EW) - The mission capability of Command, Control & Communications systems is continually threatened by the possibility of electronic countermeasures (ECM) such as spoofing and jamming. Potential adversaries put a high emphasis on ECM and have a constantly improving ECM technology base. To be responsive, each Command, Control & Communications system concept must have as little potential for ECM exploitation as possible, electronic counter-counter measure (ECCM) technology base must be vigorous, and incorporation of ECCM into systems must be timely. [1]

Engineering Change - An alteration in the configuration item or items, delivered, to be delivered, or under development, after formal establishment of its configuration identification. [4]

Engineering Change Proposal (ECP) - A term which includes both a proposed engineering change and the documentation by which the change is described and suggested. [4]

Engineering Management - The management of the engineering and technical effort required to transform a military requirement into an operational system. It includes the system engineering required to define the system performance parameters and prefered system configuration to satisfy the requirement, the planning and control of technical program tasks, integration of the engineering specialties, and the management of a totally integrated effort of design engineering, specialty engineering, test engineering, logistics engineering, and production engineering to meet cost, technical performance and schedule obj. tives. The engineering management task of the government program office assures that the technical functions in the program office are properly planned and implemented, and that the technical functions performed under contract are tailored, monitored, and controlled to best meet the needs of the system or program. These functions (together with certain supporting functions) are: Systems Engineering (including Requirements Engineering), Design Engineering, Specialty Engineering, Test Engineering, Production Engineering, Logistics Engineering, Civil Engineering, Human Factors Engineering, Configuration Management, Technical Data Control, and Technical Program Planning and Control. [10]

Engineering Simulation - Engineering simulation is a further refinement of the scientific simulation in which the final software design is evaluated by driving this software with realistic input data generated from representative scenarios. These simulations, executed on a general purpose computer, are characteristic of the types of tools needed in system and software requirements definition and evaluation. [9] (See also functional simulation, discrete event simulation, scientific simulation)

Environmental Conditions - Environments that the system or equipment is expected to experience in shipment, storage, service, and use. The following subjects should be considered for coverage: natural environment (wind, rain, temperature, etc.); induced environment (motion, shock, noise, etc.); electromagnetic signal environment; shipboard magnetic environment; and environmental conditions due to enemy action (over-pressure, blast, underwater explosions, radiation, etc.).

External Interface - (Also called Intra-System Interface). The interfaces between the system being specified and other systems with which it must be compatible. [3] (See also Interface)

Formal Qualification Tests (FQT) - A formal test conducted in accordance with the Air Force-approved test plans and designed to be a complete and comprehensive test of the CPCI prior to FCA. It is conducted after the design process culminates (AFR 80-14, Vol. II). [7]

Full-Scale Development Phase (FSD) - The period when the system/equipment and the principal items necessary for its support are designed, fabricated, tested, and evaluated. The intended output is, as a minimum, a preproduction system which closely approximates the final product, the documentation necessary to enter the production phase, and the test results which demonstrate that the production product will meet stated requirements. (AFR 800-2) [1] (see also Acquisition Life Cycle)

Function (Functional Requirement Set, Functional Requirements) - A function is a discrete activity within a system. The functional requirements represent the total discrete system activities required to achieve a specific objective, this is most often referred to as the mission objective. A functional requirement identifies what must be accomplished without identifying any aspect concerning the means such as hardware, computer programs, personnel, facilities, or procedural data. Functional requirements represent a problem statement devoid of any overtones or specifics regarding real or conceptual solutions which satisfy any or part of the needed functions.

Note 1: Functions take on different meanings within the three types of system documentation as required by MIL-STD-483 (USAF). Type A specification functions are defined for the system as a whole as defined above. Type B5 specifications define CPCI function to include the inputs, processing, and outputs. The Computer Program Components (CPCs) of the Type C5 specification may correspond to the functions in the Type B5 specification, if the B5 requirements satisfy the computer program developer's design approach. (See [11], para. 4.3.1 and Appendix A4)

For the purpose of requirements engineering, functions are defined to be the same as Type A Specification functions. In documenting functions in Type B5 specifications, the associated inputs and outputs are included.

Note 2: The revised AFR 57-1 provides a slightly different definition of a function: The action for which a system or equipment item is specially fitted or used. [13]

<u>Functional Analysis</u> - System functions and sub-functions shall be progressively identified and analyzed as the basis for identifying alternatives for meeting system requirements. System functions as used above include the mission, test, production, deployment, and support functions. All contractually specified modes of operational usage and support shall be considered in the analysis. System functions and sub-functions shall be developed in an iterative process based on the results of the mission analysis, the derived system performance requirements, and the synthesis of lower-level system elements. Performance requirements shall be established for each function and sub-function identified. When time is critical to a performance requirement, a time line analysis shall be made. [10] (See also Systems Engineering)

<u>Functional Area</u> - A distinct group of system performance requirements which, together with all other such groupings, forms the next lower level breakdown of the system on the basis of function. [4] The second level in the functional hierarchical structure. (See also System Segment, CI and CPCI)

<u>Functional Characteristics</u> - Quantitative performance, operating and logistic parameters and their respective tolerances. Functional characteristics include all performance parameters, such as range, speed, lethality, reliability, maintainability, and safety. (DOD Directive 5010.19) [4]

<u>Functional Hierarchical Structure</u> - This form of organization is suited for structuring system functional requirements in a logical arrangement of subordinate discrete activities which must be performed. The functions of the system are grouped into higher levels of organization representing the

first possible breakout of the system. Upper-level functions are refined by the identification of subordinate levels. Each level of the hierarchy is limited to six functions or less. (See also System Segment, Functional Area, Configuration Item, Computer Program Configuration Item)

Functional Performance - The ability of the software to satisfy its mission requirements as allocated from the System Specification and as contractually specified in the Development Specification. [2]

Functional Requirements - see Function

Functional Simulation - A functional simulation generally consists of a set of building blocks which functionally define the basic elements of the system such as the sensor models, aircraft dynamics, navigation, weapon delivery, and the environment. This type of simulation is used to analyze performance in support of system requirements definition. To support this analysis activity, the simulation may be utilized to generate mission scenarios in order to evaluate system performance parameters and tradeoff studies associated with various system elements, such as the sensors, etc. [9] (See also discrete event simulation, scientific simulation, engineering simulation)

Government Furnished Property (GFP) - Contracts may require the use of GFP, either as end item design requirement or as a part of the system. In such cases, a schedule is included in the contract for delivery of the GFP to the contractor at a date permitting his evaluation for serviceability before it is needed for installation. Engineering data on the GFP must be provided at a date which permits the contractor's engineers to incorporate it, or the interface with it, into the design of the system. [1]

Human Engineering - Human Engineering is usually a contractor design and review process that interacts with other processes such as mission requirements analysis, functional analysis and requirement allocation, the development of workspace mockups, equipment detail design, test and evaluation, etc. (MIL-H-46855A applies.) The contractor is tasked to identify and investigate areas where interactions of human performance and other elements of the system are critical to the system-effectiveness. The contractor's end task is to translate controller/situation, human/information and man/machine functional interface requirements into human engineering design criteria for incorporation into system, equipment, software and facility specifications and delivered products. [1] (See also Human Factors Engineering)

Human engineering requirements for the system/item should be described in specifications and applicable documents (e.g., MIL-STD-1472) included by reference. The specifications should also specify any special or unique requirements, e.g., constraints on allocation of functions to personnel, and communications and personnel/equipment interactions. Included, should be those specified areas, stations, or equipment that require concentrated human engineering attention due to the sensitivity of the operation or criticality of the task, i.e, those areas where the effects of human error would be particularly serious. [3]

Interfaces between software and the user should be specified in the Development (Part I) Specification. Inputs and outputs should be self explanatory, easy to learn and understand, unambiguous, and designed to avoid misinterpretation. [2]

Human Factors Engineering - This function is a part of the mainstream engineering effort throughout the system life cycle. It uses data from, and contributes to, the system engineering process in developing a best mix of specification requirements. Its objective is to ensure that the human component of the system can safely and effectively operate, maintain, support, and control the system in its intended operational environment. It is also concerned with providing engineering data for use in hardware, software, or people cost-effective trade studies, and with developing plans for training and training equipment (see AFR 800-15). [6] (See also Engineering Management and Human Engineering)

Implementing Command - The command or agency designated by Program Management Directive (PMD) as responsible to achieve the program objectives or program phase objectives established in the PMD. (Ref: AFR 800-2) [13]

The Air Force command responsible for the acquisition of the system (subsystem or item). The procuring activity is usually resident within the Implementing Command. Program management responsibility normally is transferred to the designated supporting command according to a predetermined agreement. Similarly, the responsibility of system operation and maintenance is turned over to the using command. [8]

Information Flow - The description of the flow of information into, within, and out of the system. The information flow builds upon the I/O hierarchical structure by providing a means of analyzing the system as an information processing system. During this analysis, the flow relationships between external system inputs and resulting outputs are identified. This method permits the various relationships between associated functions and the internal information necessary to support the derivation of the output to be identified. The flow associations between system information are described using the information-flow relationships: USES, DERIVES, UPDATES, PROVIDES, and RECEIVES. The informational flow indicates only the relationship between system functions, system information (external and internal system I/O), and using activities (organizations, operational units, or positions) and does not imply any lapse in time or intermediate I/O being used, derived, or updated.

Initial Operational Capability (IOC). The first attainment of the capability to employ effectively a weapon, item of equipment, or system of approved specific characteristics, and which is manned or operated by an adequately trained, equipped, and supported military unit or force. (Source: JCS Pub. 1) [13]

I/O Hierarchical Structure - The logical hierarchical description of the discrete system inputs and outputs (external I/O) and the internal information requirements necessary for the system's operation. The emphasis on the I/O structure is to arrange the information requirements into structures by breaking the information into logical subordinate parts or simply as groupings of information. The well-organized structure is effective in communicating the I/O requirements and for identifying missing I/O requirements.

Interface - The functional and physical characteristics required to exist at a common boundary between two or more equipments/computer programs. Interfaces between equipment/computer programs provided by different developing agencies (contractors), or between development items and government furnished property or external systems, require explicit documentation. [8] (See also External Interface and Internal Interface)

Life Cycle Cost (LCC). The total cost of an item or system over its full life. It includes the cost of acquisition, ownership (operation, maintenance, support, etc.) and, where applicable, disposal. To be meaningful, an expression of life cycle cost must be placed in context with the cost elements included, period of time covered, assumptions and conditions applied, and whether it is intended as a relative comparison or absolute expression of expected cost effects. (Source: AFR 800-11) [13]

Internal Interface (also called Inter-System Interface) - The interfaces between and within the system being specified (e.g., between system segments, functional areas, configuration items) [3] (See also Interface)

Life Cycle Cost Analysis - Life Cycle Cost Analysis is performed by the contractor periodically throughout the acquisition to access the cost of acquisition and ownership. This effort results in an identification of the economic consequences of system design alternatives. [10] (See also Systems Engineering)

Logical Organizational Relationships - Logical organizational relationships are shown by structuring the discrete functions and the information requirements (external and internal input/output) of the system into hierarchical structures: Functional Hierarchical Structure, and I/O Hierarchical Structure.

Logistics Engineering - This function provides inputs to the systems engineering process in all acquisition phases. In general, these inputs are the support environment descriptors and constraints. This function uses the technical data developed by the systems engineering process to refine the support plans, concepts, and requirements for system support in the deployment phase and in operational utilization. The logistics engineering function is a part of the mainstream engineering effort to develop and achieve a supportable and cost-effective system. This function uses the detailed drawings which are prepared by design engineering to develop the specific support requirements; that is, to develop such specific support items as tools, test equipment, personnel skills, and maintenance procedures. (For other information concerning logistics engineering responsibilities, see AFR 800-8 and AFP 800-7.) [6] (See also Engineering Management)

Logistics Support Analyses - The contractor is usually tasked to conduct logistic support analyses leading to the definition of support needs (e.g., maintenance equipment, personnel, spares, repair parts, technical orders, manuals, transportation and handling, etc.). These analyses address all levels of operations and maintenance and results in requirements for support. [10] (See also Systems Engineering)

Maintainability - Closely related and inseparable from Reliability is the specialty, Maintainability. Maintainability is a characteristic of the design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time when the maintenance is performed using prescribed procedures and resources. (See also Reliability and Availability) [1] The revised AFR 57-1 emphasizes the following definition: a measure of the time or maintenance resources needed to keep an item operating or restore it to operational (or in the case of certain munitions, serviceable) status. Maintainability may be expressed as the time to do maintenance, as the total required manpower, or as the time to restore a system to operational (or serviceable) status. (Source: AFR 80-5) [13]

Numerical maintainability requirements shall be stated in such terms as mean-time-to-repair (MTTR) or maintenance man-hours per flight/operational hour. Determination of realistic requirements is necessary. Qualitative requirements for accessibility, modular construction, test points, and other design requirements may be specified as required. [3]

Specifications shall specify the quantitative maintainability requirements. The requirements shall apply to maintenance in the planned maintenance and support environment and shall be stated in quantitative terms. Examples are:

a. Time (e.g., mean and maximum downtime, reaction time, turnaround time, mean and maximum times to repair, mean time between maintenance actions).

b. Rate (e.g., maintenance manhours per flying hour, maintenance manhours per specific maintenance action, operational ready rate, maintenance hours per operating hour, frequency of preventive maintenance).

c. Maintenance complexity (e.g., number of people and skill levels, variety of support equipment).

d. Maintenance action indices (e.g., maintenance costs per operating hour, manhours per overhaul). [3]

Maintainability as applied to software is specification, design, and development of code in a manner which facilitates the task of modification to correct deficiencies and to satisfy new or changing requirements. A potential source of confusion exists regarding subtle distinctions between the hardware and software definition of maintainability. Hardware maintenance is the restoration of hardware to its original design, whereas software maintenance is defined as both error correction and modification of the original design (both of which imply change rather than restoration)

Since there is little chance that the usage of either set of definitions will be discontinued, the procuring agency should bear these differences in mind when participating in the establishment of maintainability criteria for the total system. Software maintenance features in terms of growth requirements may be specified in the Development (Part I) Specification. Additional features such as modularity should be requested in the RFP, responded to in the CPDP, and implemented by the contractor in the design, and reflected in the Product (Part II) Specification. [2]

Maintenance Concept. A description of maintenance considerations and constraints. A preliminary maintenance concept is developed and submitted as part of the preliminary operational concept for each alternative solution candidate by the operating command with the assistance of the implementing and supporting commands. The preliminary maintenance concept is refined during the demonstration and validation phase to become the system maintenance concept during full scale engineering development (FSED). During FSED, the system maintenance concept is expanded in scope and detail and removed from the system operational concept to become the maintenance plan. (Source: AFR 66-14) [13]

Milestone Zero Decision. The program initiation decision by competent authority that valid mission need exists and alternative solutions should be systematically and progressively identified and explored. Secretary of Defense approval of the need is required to initiate major system acquistion programs. Secretary of the Air Force approval is required to initiate Air Force designated acquisition programs (AFDAP). HQ USAF approval by PMD is required to initiate all other acquisition programs. [13]

Mission Area. A segment of the defense mission as established by the Secretary of Defense. (Source: AFR 800-2) [13]

Mission Area Analyses. Continuous analysis of assigned mission responsibilities in the several mission areas to identify deficiencies in the current and projected capabilities to meet essential mission needs and to identify opportunities for the enhancement of capability through more effective systems and less costly methods. Missions area analysis should conform with short, mid, and long range planning guidance. The objectives of mission area analysis are to identify capability deficiencies and assess the relative values of operational needs. [13]

Mission Area Planning. A continuous HQ USAF and command planning activity which directs and coordinates mission area analysis and uses the product of that analysis to help make program, budget, modification and acquisition, force structure, strategy and tactics decisions. [13]

Mission Element. A segment of a mission area critical to the accomplishment of the mission area objectives and corresponding to a recommendation for a major system or designated non-major system capability as determined by the Air Force. (Ref: AFR 800-2) [13]

Mission Element Need Analysis (MENA). A mandatory attachment of the SON which cites the command mission and tasks, documents of the salient results of the mission analysis which identified the operational deficiency, states command needs for mission task performance, and provides constraints on acceptable solutions. [13]

Mission Element Need Statement (MENS). A statement prepared by HQ USAF to identify and support the need for a new or improved mission capability. It is normally based on one or more SONs. The mission need may result from a projected deficiency or obsolescence in existing systems, a technological opportunity, or an opportunity to reduce operating cost. The MENS is submitted to the SECDEF or SAF as appropriate for a Milestone 0 decision. (Ref: DOD Directive 5000.2) [13]

Mission Reliability. A measure of the ability of a system to complete its planned mission or function. Mission reliability may be expressed as Mission Completion Success Probability (MCSP), Mean Mission Duration (MMD), or as Mean Time Between Critical Failure (MTBCF) as appropriate. (Source: AFR 80-5) [13]

Mission Requirements Analysis - Impacts of the stated system operational characteristics, mission objectives, threat, environmental factors, minimum acceptable system functional requirements, technical performance, and system figure(s) of merit as stipulated, proposed, or directed for change are analysed during the conduct of the contract. These impacts are examined continually for validity, consistency, desirability, and attainability with respect to current technology, physical resources, human performance capabilities, life cycle costs, or other limitations. The output of this analysis will either verify the existing requirements or develop new requirements which are more appropriate for the mission. [10] (See also Systems Engineering and System Capability requirements)

Operability. (Sometimes called System-Effectiveness or System Operational Effectiveness) - Operability includes system availability and dependability. Availability incorporates the aspects of reliability and maintainability; dependability incorporates the aspects of survivability and vulnerability (S/V). Each of these operability categories may be influenced by design related issues, policy related impact, or non-controllable factors.

Operating Command. The command or agency primarily responsible for the operational employment of a system, subsystem or item of equipment. The operating command usually submits the SON. The operating command is a participating command. (Ref: AFM 11-1, Vol I) [13]

Operational Concept. A statement about intended employment of forces that provides guidance for posturing and supporting combat forces. Standards are specified for deployment, organization, basing, and support from which detailed resource requirements and implementing programs can be derived. (Source: (AFM 11-1, Vol I) [13] influencing the system/equipment design. On the other hand, the manpower agency may request program office support in determining the appropriate manning for a new or complex system. In this case the program office can task the contractor to perform studies for determining the manpower requirements. [1]

Physical Characteristics - Quantitative and qualitative expressions of material features, such as composition, dimensions, finishes, form, fit, and their respective tolerances (DOD Directive 5010.19). [4] These characteristics in a development, product or material specification shall set forth requirements such as weight limits, dimensional limits, etc., necessary to assure physical compatibility with other elements and not determined by other design and construction features or referenced drawings. They shall also include considerations such as transportation and storage requirements, security criteria, durability factors, health and safety criteria, command control requirements, and vulnerability factors. [3] (See also Physical Requirements)

Physical Requirements - Physical requirements are those requirements which constrain or significantly influence the design solution in a physical manner. The physical constraints include power, physical features (size and weight), environmental considerations (controlled or natural), human performance capabilities and limitations (human factors), predetermined internal system interfaces (inter-system interfaces) and external system interfacing (intra-system interfaces), use of existing equipment (off-the shelf) and Government Furnished Property (GFP), and use of standard parts. (See also Physical Characteristics)

Preliminary Qualification Tests (PQT) - A formal test conducted in accordance with Air Force-approved test plans and designed to be an incremental process which provides visibility and control of the computer program development during the time period between CDR and FQT. A PQT should be conducted for those functions which are critical to the CPCI (AFR 800-14, Vol. II). [7]

Procuring Activity (Also called Procuring Agency) - The collection of administrative, management and technical expertise which is organized under a program manager directly responsible for the acquisition of a system. The term System Program Office (SPO) is used in the Electronic Systems Division (ESD) of AFSC to designate a procuring activity responsible for a large system acquisition. [8] (See also Program Office and Implementing Command)

Production Engineering - This function uses the technical data developed through the systems engineering process to develop the plans and procedures for tooling, materials, quality assurance, and manufacturing. The production engineering function is a part of the mainstream engineering effort to develop and achieve producible and cost-effective design solutions. (For other information concerning production engineering responsibilities, see AFR 800-9) [6] (See also Engineering Management)

Production Engineering Analysis - Production engineering analysis is an integral part of the system engineering process. It includes producibility analyses, production engineering inputs to system effectiveness, trade-off studies, and life cycle cost analyses and the consideration of the materials, tools, test equipment, facilities, personnel, and procedures which support manufacturing in RDT&E and production. Critical or special producibility requirements are identified as early as possible and are an input to the program risk analysis. Where critical or special production engineering requirements limit the design, these requirements are included in applicable specifications. Long lead time items, material limitations, transition from development to production, special processes, and manufacturing limitations are considered and documented during the system engineering process. The contractor identifies and takes necessary steps to reduce high-risk manufacturing areas as early as possible. [10] (See also Systems Engineering)

Production Phase - The period from production approval until the last system/ equipment is delivered and accepted. The objective is to efficiently produce and deliver effective and supportable systems to the operating units. It includes the production and deployment of all principal and support equipment. (AFR 800-20 [1])

Product Specification - A document or series of documents which contain the detailed technical description of the CPCI as designed and coded. It is a complete description of all routines, limits, timing, flow, and data base characteristics of the computer program, limits, timing, flow, and data coded instructions. Equivalent to "Part II CPCI specification" or "Type C5 Specification". [7] (See also Type C Specification and Specifications)

Program Management Directive (PMD) - The official HQ USAF management directive used to provide direction to the implementing and participating commands and satisfy documentation requirements. It will be used during the entire acquisition cycle to state requirements and request studies as well as initiate, approve, change, transition, modify or terminate programs. The content of the PMD, including the required HQ USAF review and approval actions, is tailored to the needs of each individual program. (AFR 800-2) [1]

Program Management Plan (PMP) - The document developed and issued by the Program Manager which shows the integrated time-phased tasks and resources required to complete the task specified in the PMD. It defines the support required from all participating organizations, is tailored to the needs of each individual program, and contains only that information deemed necessary by the program manager. (AFR 800-2) [1]

Program Office (PO) - The field office organized by the program manager to assist him in accomplishing the program tasks. (AFR 800-2) (See also Procuring Activity) [1]

PROVIDES - This relationship indicates that a using activity is the source of the external output. (See also Information Flow)

Quality Requirements. The term 'quality requirements' denotes system requirements which are complete, consistent, testable, and traceable. This characteristic is the result of the requirements being discretely identified and well-organized. (see also Requirements Engineering)

RECEIVES - This relationship indicates that a using activity is the recipient of the external output. (See also Information Flow)

Reliability - As defined in AF Regulation 80-5, Reliability and Maintainability Programs for Systems, Sybsystems, Equipment, and Munitions, Reliability is the probability that a part, components, subassembly, assembly, subsystem or system will perform for a specified interval under stated conditions with no malfunction or degradations that require corrective maintenance actions. Hardware reliability may also be expressed in terms such as Mean Time Between Failure (MTBF) or Mean Time Between Maintenance Action. [1]

Reliability requirements shall be stated numerically with confidence levels, as appropriate, in terms of mission success or hardware mean time between failures. Initially, reliability may be stated as a goal and a lower minimum acceptable requirement. During contract definition, or equivalent period, realistic requirements shall be determined and incorporated in the specification with requirements for demonstration. Reliability requirements shall never be stated as a goal in Type C (product) specifications. [3]

Reliability is a difficult and perhaps inappropriate term when applied to software because this item has an entirely different meaning for hardware. Since a computer program never wears out it is virtually impossible to predict or analyze failure rates. Any failure of the computer program is a latent design deficiency and its occurrence cannot be adequately predicted. In this respect a computer program cannot be designed for reliability and cannot be tested or evaluated for reliability. Reliability should not apply to computer programs as end items although the computer programs may be used to enhance system reliability. [2] (See also Availability and Maintainability)

Required Operational Capability (ROC) - The ROC identifies the need for a new or improved operational capability. The formal numbered document used under previous editions of AFR 57-1, (27 Nov 1963 through 31 Aug 1977) to identify an operational need and to request a new or improved capability for the operating forces. [13] Once the ROC is validated by HQs USAF, the PMD, which authorizes AFSC to establish a Program Office cadre, is issued. [2]

Requirements Allocation - Each function and sub-function shall be allocated a set of constraint requirements. These requirements shall be derived concurrently with the development of functions, time-line analyses, synthesis of system design, and evaluation performed through trade-off studies and system/ cost effectiveness analysis. Time requirements which are prerequisites for a function or set of functions affecting mission success, safety, and availability shall be derived. The derived

... addresses the issues of system survivability, vulnerability (S/V) and external electromagnetic interference. Survivability is the ability of the system to achieve its mission under the conditions of a man-made hostile environment. In addition the system may

requirements shall be stated in sufficient detail for allocation to hardware, computer programs, procedural data, facilities, and personnel. When necessary, special skills or peculiar requirements will be identified. Allocated requirements shall be traceable through the analysis by which they were derived to the system requirement they are designed to fulfill. [10] (See also Systems Engineering)

Requirements Analysis - (See Requirements Engineering)

Requirements Definition - (See Requirements Engineering)

Requirements Engineering - An iterative process of defining the system requirements and analyzing the integrity of the requirements. This process involves all areas of system development preceding the actual design of the system. The products of the requirements engineering process can be evaluated for completeness, consistency, testability, and traceability. The essential goal of requirements engineering is to thoroughly evaluate the needs which the system must satisfy. (See also Engineering Management)

Requirement Types - See System Requirements

Requirements Traceability - See Traceability

Safety - Requirements for system safety are described to preclude or limit hazard to personnel, equipment, or both. To the extent practicable, these requirements are imposed by citing established and recognized standards. Limiting safety characteristics peculiar to the item due to hazards in assembly, disassembly, test, transport, storage, operation or maintenance are stated when covered neither by standard industrial or service practices nor the system specification. "Fail-safe" and emergency operating restrictions are included when applicable. These include interlocks and emergency and standby circuits required either to prevent injury or provide for recovery of the item in the event of failure. [3] (See also System Safety)

Scientific Simulation - Scientific simulation is the primary simulation used in detailed computer program requirements definition and algorithm design. Scientific simulation consists of a functional simulation (for example, FORTRAN version) of the proposed end-item software, interfaced with simulations representing sensor and environmental models. Such a scientific simulation allows the study of the major end-item software, and provides further information to be used for system performance evaluation. [9] (See functional simulation, discrete event simulation, engineering simulation)

Segment - (See System Segment)

Simulation - See Functional Simulation, Discrete Event Simulation, Scientific Simulation, Engineering Simulation.

Software - Software denotes computer programs and computer data. A computer program is a series of instructions or statements in a form acceptable to a computer, designed to cause the computer to execute an operation or operations. Computer programs include operating systems, assemblers, compilers, interpreters, data maintenance/diagnostic programs, as well as applications programs such as payroll, inventory control, operational flight, strategic, tactical automatic test, crew simulator, and engineering analysis. Computer programs may be either machine-dependent or machine-independent, and may be general-purpose in nature or be designed to satisfy the requirements of a specialized process or particular users. Computer data is a collection of data in a form capable of being processed and operated on by a computer, such as a data base, or analog or digital inputs to a computer program that are necessary for its operation. [2], [8] (See also Computer Program)

Speciality Engineering - This term refers to the engineering efforts of reliability, maintainability, safety, survivability, vulnerability, corrosion prevention, structural integrity, etc. These engineering functions are part of the mainstream engineering effort to develop a best mix of specification requirements and achieve cost-effective design solutions. [6] (See also Engineering Management)

Specification (See also Systems Engineering) - A document intended primarily for use in procurement, which clearly and accurately describes the essential technical requirements for items, materials or services including the procedures by which it will be determined that the requirements have been met. (DOD Directive 4120.3) [4] MIL-STD-490 and MIL-STD-483 Specification types are:

System specification. A document which states the technical and mission requirements for a system as an entity, allocates requirements to functional areas (or configuration items), and defines the interfaces between or among the functional areas. (See also Type A) [4]

Development specification. A document applicable to an item below the system level which states performance, interface, and other technical requirements in sufficient detail to permit design, engineering for Service use, and evaluation. (see also Type B) [4]

Product specification. A document applicable to a production item below the system level which states item characteristics in a manner suitable for procurement, production and acceptance. (See also Type C) [4]

Statement of Operational Need (SON). A formal numbered document used to identify an operational deficiency and state the need for a new or improved capability for USAF forces. Operational needs are based on short term and long term capability objectives and may result from a projected deficiency or obsolescence in existing capabilities, a technological opportunity, or an opportunity to reduce operating/support cost. It usually begins the system acquisition process and is normally followed by the conceptual phase, however, any appropriate phase may follow. Satisfying a SON will normally require a combination of research, development, test, modification, or acquisition efforts that will enhance USAF forces' capabilities. [13]

Supporting Command - A command providing direct support to a system or test program. Examples include the Air Force Logistics Command (AFLC) and the Air Training Command (ATC). See also implementing command and using command. [8] The revised AFR 57-1 provides the following definition: The command assigned responsibility for providing logistics support; it assumes program management responsibilty from the implementing command. The supporting command is a participating command. (Ref: AFR 800-2) [13]

Synthesis - Sufficient preliminary design is accomplished to confirm and assure completeness of the performance and design requirements allocated for detail design. The performance, configuration, and arrangement of a chosen system and its elements and the technique for their test, support, and operation are portrayed in a suitable form such as a set of schematic diagrams, physical and mathematical models, computer simulations, layouts, detailed drawings, and similar engineering graphics. These portrayals shall illustrate intra- and inter-system and item interfaces, permit traceability between the elements at various levels of system detail, and provide means for complete and comprehensive change control. This portrayal is the basic source of data for developing, updating, and completing (a) the system, configuration item, and critical item specifications, (b) interfacing control documentation; (c) consolidated facility requirements; (d) content of procedural handbooks, placards, and similar forms of instructional data; (e) task loading of personnel; (f) operational computer programs; (g) specification trees; and (h) dependent elements of work breakdown structures. [10] (See) also Systems Engineering)

System - A composite of items, assemblies (or sets), skills, and techniques capable of performing and/or supporting an operational (or non-operational) role. A complete system includes related facilities, items, material, services, and personnel required for its operation to the degree that it can be considered a self-sufficient item in its intended operational (or non-operational) and/or support environment. (AFR 65-3) [1],[8],[4]

System Acquisition Process. A sequence of specified decision events and phases of activity directed to achievement of established program objectives in the acquisition of Defense systems and extending from approval of a mission need through successful deployment of the Defense system or termination of the program. (Source: AFR 800-2) [13]

System/Acquisition Life Cycle - Normally, it consists of five phases (Conceptual, Validation, Full-Scale Development, Production, and Deployment) with key decision points between each of the first three phases (Program, Ratification, and Production Decisions). A program may skip a phase or have program elements in any or all other phases. (See AFR 800-2 and AFSCP 800-3) (See also Acquisition Life Cycle) [1]

System Capability Requirements - The mission oriented needs which the system must perform to satisfy the requirements of the using agency. (See also Mission Requirements Analysis)

System/Cost Effectiveness Analysis - A continuing system/cost effectiveness analysis insures that engineering decisions, resulting from the review of alternatives, are made only after considering their impact on system effectiveness and cost of acquisition and ownership. The contractor is tasked to identify alternatives which would provide significantly different system effectiveness or costs than those based upon contract requirements. [10]

System Design Concept. An idea expressed in terms of general performance, capabilities, and characteristics of hardware and software oriented either to operate or to be operated as an integral whole in meeting a mission need. (Source: OMB Circular A-109) [13]

Systems Engineering - The application of scientific and engineering efforts to transform an operational need or statement of deficiency into a description of system requirements and a preferred system configuration that has been optimized from a life cycle cost viewpoint. The process of systems engineering has three principal elements: functional analysis, synthesis; and trade studies or cost-effectivess optimization. The process uses a sequential and iterative methodology to reach cost-effectivess solutions. The technical information developed in this process is used to plan and integrate the engineering effort for the system as a whole, during the definition, design, test and evalution, production, deployment, support, and modification of a system or equipment item. (AFR 800-3) [1] (See also Engineering Management)

System engineering for the total system or a functional area (system element or segment) is normally vested in a single contractor or Government agency. System engineering as it relates to configuration management, is the application of scientific and engineering efforts to transform an operational need into a description of system performance parameters and a system configuration must be ultimately called out in the CI specifications. In this way, the system engineering agency or contractor generates requirements for configurations which will satisfy the operational need, constrained technically only by the content of the system specification. The system engineering agency or contractor is responsible for assessing the impact of changes to CI specifications or to the system specification. This includes modifications to operational systems. (See MIL-STD-490 for system engineering criteria.) [1]

The following typical tasks are conducted (as appropriate) in performing system engineering (see separate definitions for each):

Mission Requirements Analysis
Functional Analysis
Requirements Allocation
Synthesis
Logistics Support Analysis
Life Cycle Cost Analysis
Trade-Off Studies
Production Engineering Analysis
Specifications [10]

System Engineering Management Plan (SEMP) - A contractor's proposal describing this approach to system engineering management to be applied in a specific acquisition contract. The SEMP normally consists of three major parts: (1) System Engineering, (2) Technical program planning and control, and (3) Engineering integration. (MIL-STD-499A) [3,5,8]

System Flow Relationships - System flow relationships can be shown be organizing the discrete requirements in terms of control flow and information flow.

System Requirements - System Functions and Constraints

System Safety - Defined by MIL-STD-882 to be the optimum degree of safety within the limits of operational effectiveness, time and cost, attained through specific application of system safety management and engineering principles throughout all phases of a system's life cycle. It is very important to realize that system safety is concerned with the safety of both personnel and equipment. The application of this discipline to ensure the preservation of equipment immediately expands its scope beyond that of the traditional safety field, and establishes it as an engineering area. As implied above, the basic guidance document for system safety is MIL-STD-882, System Safety Program for Systems and Associated Subsystems and Equipment: Requirements for. This is a very broad document and must be tailored to fit the individual program. The other basic document is AFR 127-8, Responsibilities for USAF System Safety Engineering Programs, and the AFSC supplement thereto. This gives specific requirements to be applied to most programs. [1] (See also Safety)

Systems Operational Concept (SOC) - A formal document that describes the intended purpose, employment, deployment, and support of a system. It assists in identifying the variables associated with satisfying the operational need and provides initial guidance to operating forces for employing the new or improved system. It provides information for posturing combat forces and specifies standards for deployment, organization, basing and support from which detailed resource requirements and implementing programs can be derived. It must be compatible with long range Air Force goals and objectives and consistent with Air Force strategy, force structure, concepts for the future employment of aerospace forces, and current and emerging doctrin. Prior to FSED, it contains as an integral part, the maintenance concept prepared per AFR 66-14. [13]

System Segment - A discrete package of system performance requirements, functional interfaces and configuration items allocated to one developing agency directly responsible to the procuring activity for that part of the system's total performance. The term "system segment" can be synonymous with "subsystem" or "functional area"; however, it need not be, and can include part or all of more than one subsystem or functional area if all are the responsibility of the same agency. [8] The first level in the functional hierarchical structure. (See also Functional Area, CI, and CPCI, Type A - System Specification)

System Segment Specification - A specification similar in format to a system specification (Type A format), identifying a discrete package of system performance requirements, functional interfaces, and CIs contracted to one contractor or assigned to one Government organization directly responsible to the procuring activity for that part of a system's total performance. [5] (See System Segment, Type A - System Specification)

System Specification - A document which states all the necessary technical and mission requirements in terms of performance, allocates requirements to functional areas (or configuration items), defines the interfaces between or among the functional areas (or configuration items), and includes the test provisions to assure the achievement of all requirements. [7] (See also Type A - System Specification)

System Training Concept. A document summarizing ATC training policy based on review of user's requirements and planning factors as reflected in the SON and system operational concept and updates. Outlines conceptual guidance on T&E and deployment training planning efforts. It forms the basis for future training planning actions which are documented in the System Training Plan.

Survivability/Vulnerability (S/V) - Survivability is the capability of a system to accomplish its mission despite a man-made hostile environment. The USAF policy is that each system will have enough designed-in hardness and will be operated in a manner so that sufficient numbers will survive the expected threat.

There are direct nuclear and nonnuclear threats to virtually every Command, Control & Communications system, and there is a severe nuclear threat to the atmosphere and ionosphere, the propagation medium for radars and radio communications. Within the nuclear hardening area itself, there are several specialized disciplines. So although it is not difficult to understand the fundamentals of vulnerability and hardening, implementation of a sound survivability program usually requires a number of different specialists.

S/V is important in all phases of a system's life cycle, from concept through operations. Key milestones include the threat study, hardness specification, hardness verification (including testing), and hardness maintenance. The regulations do provide a formal mechanism for establishing survivability criteria, through the Nuclear Criteria Group and the Nonnuclear Survivability Technology Working Group. Mission Hardness design and verification must documented in such a way that AFLC and the operating command can readily maintain system hardness throughout its life, and evaluate the impacts of a changing threat.

Virtually every Command, Control and Communications system must be protected from the effects of electromagnetic pulse (EMP), a broad area nuclear effect. This can be done with sound state-of-the-art electrical engineering. Beyond EMP, hardening becomes very threat specific. [1]

Technical Data Control - This term refers to logging and managing the technical information which is developed by various engineering functions. (For other information concerning technical data control responsibilities, see AFR 310-1.) [6] (See also Engineering Management)

Technical Program Planning and Control - This term refers to the process of planning, monitoring, measuring, evaluating, directing, and replanning the management of the technical program. This process is carried out through such tasks as making risk analyses, developing and updating the work breakdown structure, accomplishing technical performance measurement, conducting technical reviews, performing change studies, and planning and implementing changes. [6] (See also Engineering Management)

Test. Any program or procedure which is designed to obtain, verify, or provide data for the evaluation of: research and development (other than laboratory experiments); progress in accomplishing development objectives; or performance and operational capability of systems, subsystems, components, and equipment items. [13]

Test Engineering - This function uses the technical data developed through the systems engineering process to develop test plans. These plans outline the test procedures and test requirements that are to be used to test the design solutions. (For other information concerning test planning, see AFR 80-14.) [6] (See also Engineering Management)

Test Requirements - The program office initiates the test planning process during the Conceptual Phase by preparing a Test and Evaluation Master Plan (TEMP). During the Validation Phase the contractor(s) initiate detailed test planning relative to hardware and computer program end-items (CIs and CPCIs). These test plans and procedures are submitted to the government for review and approval; the approved plans and procedures are the basis for subsystem and system testing. In order to test system requirements, a unique test must be associated with the appropriate end-item which incorporates requirement(s) to be tested. For those requirements which are inherent in a collection of end-items, the test of a requirement will be realized during system testing. Critical system requirements should be linked to unique end-items and be traceable to the original requirements as described in the MIL-STD-490 Type A and B specifications. Section 4 (MIL-STD-490/483 Type A and B Specifications, Quality Assurance Provisions) identifies the specific requirements for formal test and verification of the system (Type A) and subsequently its end-items (Type B). These test and verification requirements identify what specific system requirements (Section 3 of the specification) must be satisfied. Test requirements, therefore, identify the functional, performance, physical, operability, and design requirements which will be evaluated during system integration and test.

Test & Evaluation Master Plan (TEMP) - The TEMP is an overall plan which identifies and integrates the efforts and schedules of all test and check-out activities to be accomplished in the system development program. [7]

Traceability - (Requirements Traceability, Requirements Traceability Relationships) During the requirements engineering activities, sources of requirements (source documents) are referenced for each requirement identified. These source references provide the means of tracing the requirements from one set of system requirements documentation to the allocated requirements contained in the next level of system documentation, such as from a Type A to Type B specification. Sources for each requirement can also be maintained for pertinent studies, analyses, and plans: PMD, PMP, system sizing and timing studies, prototyping, simulations, test plans and procedures, and the like. The requirements and associated sources provide the means of verifying the requirements during the requirements engineering process and into later phases of the system acquisition by providing a repository of information on the system definition.

Software traceability refers to the capability to follow specific mission requirements through the various levels of specification to the actual code; and the capabilities to associate each area of code with a specified requirement. [2]

Trade-off Studies - Desirable and practical trade-offs among stated operational needs, engineering design, program schedule and budget, producibility, supportability, and life cycle costs, as appropriate, are continually identified and assessed. Trade-off studies are accomplished at the various levels of functional or system detail or as specifically designated to support the decision needs of the system engineering process. Trade-off studies, results and supporting rationale are documented in a form consistent with the impact of the study upon program and technical requirements. [10] (See also Systems Engineering)

Training Equipment - All types of maintenance and operator's training hardware, devices, visual/audio training aids and related software which (a) are used to train maintenance and operator personnel by depicting, simulating or portraying the operational or maintenance characteristics of an item, system or facility, and (b) must, by their nature, be kept consistent in design, construction and configuration with such items in order to provide required training capability.

Transportability - Any special requirements for transportability and materials handling shall be specified. The specifications shall include requirements for transportability which are common to all system equipment to permit employment, deployment, and logistic support. All system elements that, due to operational or functional characteristics, will be unsuitable for normal transportation methods, shall be identified. [3]

Two-part Specifications - Two-part specifications, which combine both development (performance) and product fabrication (detail design) specifications under a single specification number as procuring activity option. This practice requires both parts for a complete definition of both peformance requirements and detailed design requirements governing fabrication. Under this practice, the development specification remains alive during the life of the item as the complete statement of performance requirements. Proposed design changes must be evaluated against both the product fabrication and the development parts of the specification. To emphasize the fact that two parts exist, both parts shall be identified by the same specification number and each part shall be further identified as Part I or Part II, as appropriate. [3]

Type A - System specification (also Segment Specification). This type of specification states the technical and mission requirements for a system as an entity, allocates requirements to functional areas, and defines the interfaces between or among the functional areas. Normally, the initial version of a system specification is based on parameters developed during the concept formulation period or an exploratory preliminary design period of feasibility studies and analyses. This specification (initial version) is used to establish the general nature of the system that is to be further defined during a contract definition, development, or contract design period. The system specification is maintained current during the contract definition, development, or equivalent period, culminating in a revision that forms the future performance base for the development and production of the prime items and subsystems (configuration items), the performance of such items being allocated from the system performance requirements (see MIL-STD-490, Appendix I for outline of form). [3] (See also System Specifications, System Segment Specification)

Type B - Development specifications. Development specifications state the requirements for the design or engineering development of a product during the development period. Each development specification shall be in sufficient detail to describe effectively the performance characteristics that each configuration item is to achieve when a developed item is to evolve into a detail design for production. The development specification should be maintained current during production when it is desired to retain a complete statement of performance requirements. Since the breakdown of a system into its elements involves items of various degrees of complexity which are subject to different engineering disciplines or specification content, it is desirable to classify development specifications by sub-types. [3] (See also Two-part Specifications, Development Specification and Specifications)

Type B5 - Computer program development specification. (See MIL-STD-490, Appendix VI for outline of form.) This type of specification is applicable to the development of computer programs, and shall describe in operational, functional, and mathematical language all of the requirements necessary to design and verify the required computer program in terms of performance criteria. The specification shall provide the logical, detailed descriptions of performance requirements of a computer program and the tests required to assure development of a computer program satisfactory for the intended use. [3] (See also Two-part specifications, Development Specifications, and Specifications)

Type C - Product specifications. Product specifications are applicable to any item below the system level, and may be oriented toward procurement of a product through specification of primarily function (performance) requirements or primarily fabrication (detailed design) requirements.

Sub-types of product specifications to cover equipments of various complexities or requiring different outlines of form are covered in MIL-STD-490, paragraphs 3.1.3.3.1 through 3.1.3.3.5 [3]

A product function specification states (1) the complete performance requirements of the product for the intended use, and (2) necessary interface and interchangeability characteristics. It covers form, fit, and function. Complete performance requirements include all essential functional requirements under service environmental conditions or under conditions simulating the service environment. Quality assurance provisions include one or more of the following inspections: qualification evaluation, preproduction, periodic production, and quality conformance.

A product fabrication specification will normally be prepared when both development and production of the item are procured. In those cases where a development specification (Type B) has been prepared, specific reference to the document containing the performance requirements for the item shall be made in the product fabrication specification. These specifications shall state: (1) a detailed description of the parts and assemblies of the product, usually by prescribing compliance with a set of drawings, and (2) those performance requirements and corresponding tests and inspections necessary to assure proper fabrication, adjustment, and assembly techniques. Tests normally are limited to acceptance tests in the shop environment. Selected performance requirements in the normal shop or test area environment and verifying test therefore may be included. Preproduction or periodic tests to be performed on a sampling basis and requiring service, or other, environment may reference the associated development specification. Product fabrication specifications may be prepared as Part II or a two-part specification (see Two-part Specifications, Product Specification and Specifications) when the procuring activity desires a close relationship between the performance and fabrication requirements. [3]

Type C5 - Computer program product specification. (See MIL-STD-490, Appendix XIII for outline of form.) A Type C5 specification is applicable to the production of computer programs and specifies their implementing media, i.e. punch tape, magnetic tape, disc, drum, etc. It does not cover the detailed requirements for material or manufacture of the implementing medium. When two-part specifications (See Two-part Specification) are used Type B5 shall form Part I and Type C5 shall form Part II. Specifications of this type shall provide a translation of the performance requirements into programming terminology and quality assurance procedures necessary to assure production of a satisfactory program. [3] (See also Product Specification and Specifications)

UPDATES - This relationship indicates that a function on the path updates internal system information as part of its activities. (See also Information Flow)

USES - This relationship indicates that a function on the path uses external information (external input) or internal system information (internal input) in order to accomplish its activities. (See also Information Flow)

Using Command (Also called Using Agency and Using Activity) - The command primarily responsible for operational employment of a system. (See also Implementing Command and Supporting Command) [8]

UTILIZES - This relationship indicates that function on a path is dependent upon the use of one or more other functions in order to accomplish its activities. A single function or sequence of functions may be defined once and utilized as frequently as necessary in the control flow without having to be redefined (replicated) for each use. (See also Control Flow).

Validation - Comprises those evaluation, integration, and test activities carried out at the system level to ensure that the system being developed satisfies the requirements of the system specification. While the validation process has significant software implications, a software validation process, distinct from the system validation process, cannot be isolated since all evaluation and test activities that make up validation are focused at the system level. [7],[2]

Validation Phase - The period when major program characteristics are refined through extensive study and analyses, hardware development, test and evaluations. The objective is to validate the choice of alternatives and to provide the basis for determining whether or not to proceed into Full-Scale Development. (See AFR 800-2 and AFSCP 800-3) [1] (see also Acquisition Life Cycle)

Verification - The iterative process of determining whether the product of each step of the Computer Program Configuration Item (CPCI) development process fullfills all of the requirements levied by the previous step. [7],[2]

Work Breakdown Structure (WBS) - A work breakdown structure is a product-oriented family tree composed of hardware, software, services, and other work tasks which result from project engineering efforts during the development and production of a defense material item and which completely defines the project/program. A WBS displays and defines the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product. (MIL-STD-881, MIL-STD-480) [1]

DEFINITION REFERENCES

The following references are the sources of many of the preceding definitions.

[1] ESD Program Manager's Handbook, Directorate, Acquisition Support, USAF Headquarters, Electronic Systems Division (AFSC), May 1976.

[2] G. Neil, and H. I. Gold, Software Acquisition Management Guidebook: Software Quality Assurance, ESD-TR-77-255 (DDC/NTIS Accession No. AD-A047318), USAF Electronic Systems Division, August 1977.

[3] MIL-STD-490, Specification Practices, 30 October 1968.

[4] MIL-STD-480, Configuration Control-Engineering Changes, Deviations and Waivers, 30 October 1968.

[5] MIL-STD-483, Configuration Management Practices for Systems, Equipment, Munitions, and Computer Programs, 31 December 1970.

[6] AFR 800-3, Engineering for Defense Systems, 1 June 1976.

[7] H. Bratman, and M. C. Finfer, Software Acquisition Management Guidebook: Verification. ESD-TR-77-263 (DDC/NTIS Accession No. AD-A048577), USAF Electronic Systems Division, June 1976.

[8] W. L. Schoeffel, An Air Force Guide to Software Documentation Requirements, ESD-TR-76-159 (DDC/NTIS Accession No. AD-A027051), USAF Electronic Systems Division, June 1976.

[9] Management Guide to Avionics Software Acquisition, Software Acquisition Process, Vol. II, ASD-TR-76-11, USAF Aeronautical Systems Division, June 1976.

[10] MIL-STD-499A (USAF), Engineering Management, 1 May 1974.

[11] J. B. Glore, Software Acquisition Management Guidebook: Life Cycle Events, ESD-TR-77-22 (DDC/NTIS Accession No. AD-A037115), USAF Electronic Systems Division, February 1977.

[12] D. H. Johnson and John J. Marciniak, "The Systems Operational Concept - A Computer Resources Viewpoint," presented at the National Aerospace and Electronics Conference (NAECON '78), Vol. 3, pp. 1316-1321, 18 May 1978.

[13] AFR 57-1 (draft), Statement of Operational Need, 8 June 1978.

LIST OF ABBREVIATIONS

Abbreviation	Definition
ADP	Automated Data Processing
AF	Air Force
AFR	Air Force Regulations
AFSC	Air Force Systems Command or Air Force Specialty Codes
AFSCM	Air Force Systems Command Manual
CADSAT	Computer-Aided Design and Specification Analysis Tool
CDRL	Contract Data Requirements List
C^3	Command, Control, and Communications
CI	Configuration Item
CPC	Computer Program Component
CPCI	Computer Program Configuration Item
CPDP	Computer Program Development Plan
DCP	Decision Coordinating Paper
DID	Data Item Description
DoD	Department of Defense (also DOD)
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DSARC	Defense Systems Acquisition Review Council
DT&E	Development Test and Evaluation
ECM	Electronic Countermeasures
ECCM	Electronic Counter-Countermeasures
ECP	Engineering Change Proposal
EMC	Electromagnetic Compatibility
EMP	Electromagnetic Pulse
ESD	Electronic Systems Division
EW	Electronic Warfare
FORTRAN	Formula Translation (an HOL)
FOT&E	Follow-on Operational Test and Evaluation
FQR	Formal Qualification Review
FQT	Formal Qualification Test
FSD	Full-Scale Development
GFP	Government-Furnished Property
HOL	Higher Order Language
HQ	Headquarters
I/O	System External and Internal Inputs and Outputs
IOT&E	Initial Operational Test and Evaluation
MIL-STD	Military Standard
MTBF	Mean-Time-Between-Failure
MTBM	Mean-Time-Between-Maintenance
MTTR	Mean-Time-To-Repair
O&M	Operations and Maintenance
OSD	Office of the Secretary of Defense
OT&E	Operational Test and Evaluation
PMD	Program Management Directive

LIST OF ABBREVIATIONS (cont'd)

Abbreviation	Definition
PMP	Program Management Plan
PO	Program Office (see also SPO)
PQT	Preliminary Qualification Test
PSL/PSA	Problem Statement Language/Problem Statement Analyzer
QA	Quality Assurance
RADC	Rome Air Development Center
R&D	Research and Development
RFP	Request for Proposal
ROC	Required Operational Capability
SEMP	System Engineering Management Plan
SE/TD	System Engineering/Technical Direction
SOC	Systems of Operational Concept
SON	System Operational Need
SOW	Statement of Work
SPO	System Program Office (see also PO)
SS	System Specification
S/V	Survivability/Vulnerability
TEMP	Test & Evaluation Master Plan
TR	Technical Report
USAF	United States Air Force
WBS	Work Breakdown Structure

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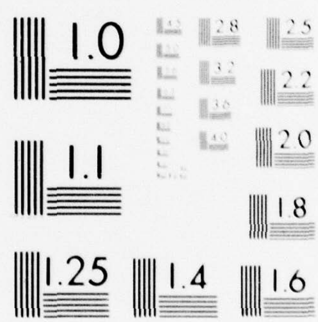

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October 1979

REQUIREMENTS STANDARDS STUDY
Requirements Engineering Guidebook

LOGICON

Daniel G. Smith
Paul B. Merrithew

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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Requirements Definition and Analysis
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Development Specification
Requirements Specification Language
Requirements Engineering Standards

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is one of three volumes which provide information and guidance for defining and analyzing military system/segment specifications and development specification requirements (MIL-STD-490/483 (USAF)). Volume I is a technical overview describing the purpose of the study, the technical approach and a history of Air Force system engineering management. It summarizes the results of the study: a Requirements Engineering Guidebook, and example using the Guidebook, associated automated tool capabilities, automated tool design approaches, and recommendations on implementing the Guidebook in the (Cont'd)

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Air Force systems acquisition life cycle. Volume II expands upon the material summarized in the first volume. Volume III is the Requirements Engineering Guidebook. The Requirements Engineering Guidebook describes the characteristics of good requirements, the various system requirement types, and the requirements engineering procedures. The requirements engineering procedures are described in the form of a procedural flow with accompanying guidelines and standards for performing fourteen requirements engineering activities. Each requirements engineering activity is supplemented by a description of the specific issues to be addressed during the first two phases of the Air Force acquisition life cycle - the Conceptual and Validation Phases.

PREFACE

This report is one of three volumes prepared to assist government and contractor personnel in managing and performing system requirements definition and analysis: requirements engineering. The primary results of this study has been the definition of guidelines and standards for requirements engineering (Requirements Engineering Guidebook) and the identification of automated aids to support the application of the guidelines and standards during the initial phases of the Air Force system acquisition life cycle - the Conceptual and Validation Phases.

This study reflects Logicon's experience with an automated requirements engineering tool applied in support of the acquistion of a large Air Force surveillance system. The Requirements Engineering Guidebook reflects the needs of an Air Force System Program Office acquisition environment; however, the basic requirements engineering principles and guidance are easily adapted to other acquisition environments.

This report was prepared by Logicon for the Air Force Systems Command (AFSC), Rome Air Development Center (RADC), Software Engineering Section. Administrative review and technical coordination of this report have been accomplished for RADC by Mr. Michael Landes (project officer).

Review of this report was accomplished at RADC, by Electronic Systems Division (AFSC/ESD) personnel at Hanscom, AFB, and by Logicon personnel. Special thanks to the many reviewers and for the patience and skills of Ms. Marcia Brehm and Ms. Deborah Queen for the technical typing, proofing, and revisions.

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SECTION 1 INTRODUCTION

1.1 Purpose

The Requirements Engineering Guidebook provides guidance and standards for government and private engineering personnel in defining and analyzing the requirements for a system. This guidebook addresses the initial phases of Air Force system acquisition (Conceptual and Validation Phases) and is intended to provide guidance for the acquisition of large-scale systems. However, the guidance can be applied to smaller, less complex systems and can be used in acquisition environments other than the Air Force. This document contains the guidelines and standards for requirements engineering and documentation and provides the framework for tailoring the requirements engineering activities to the specific needs of individual programs.

1.2 Scope

This guidebook supplements the engineering requirements and guidance provided by AFR 800-3, MIL-STD-499A, MIL-STD-490, and MIL-STD-483 (USAF).

1.2.1 Program Office Requirements Engineering

This document provides guidelines and standards for Air Force program offices in the following areas:

- Performing requirements engineering activities and producing system documentation in conjunction with preparation of solicitation documents.
- Contracting for the performance of the preceding activities by support contractors.
- Contracting for requirements engineering during the subsequent phases after contract award by the prime contractor or subcontractors.

- establishing the criteria for evaluating requirements engineering progress and products.

1.2.2 Contractor Requirements Engineering

This document provides information to government contractors in the following areas:

- Performing requirements engineering activities and producing system requirements documentation.

- Establishing the criteria for evaluating requirements engineering progress and products.

- A means of establishing an engineering effort and a System Engineering Management Plan (SEMP)

1.3 Definitions

1.3.1 System

A composite of items, assemblies (or sets), skills, and techniques capable of performing and/or supporting an operational (or non-operational) role. A complete system includes related facilities, items, material, services, and personnel required for its operation to the degree that it can be considered a self-sufficient item in its intended operational (or non-operational) and/or support environment. (AFR 65-3)

1.3.2 Requirements Engineering

Requirements Engineering is an iterative process of defining the system requirements and analyzing the integrity of the requirements. This process involves all areas of system development preceding the actual design of the system. The products of the requirements engineering process can be evaluated for completeness, consistency, testability, and traceability. The essential goal of requirements engineering is to thoroughly evaluate the needs which the system must satisfy.

1.3.3 Quality Requirements

The term 'quality requirements' is used throughout this guidebook to denote system requirements which are complete, consistent, testable, and traceable. This characteristic is the result of the requirements being discretely identified and well-orgainzed as discussed in the sections to follow.

1.3.4 Other Definitions

For definitions of other terms used in this guidebook, see Appendix A.

1.4 Contents

The remainder of this guidebook consists of three sections and one appendix, as follows:

- Section 2 - Quality Requirements Characteristics.
  Provides a description of the two requirements characteristics: discrete and well organized. This discussion is followed by a description of three forms of well-organized requirements: hierarchical structures, system flows, and requirements traceability.

- Section 3 - System Requirement Types.
  Provides a concise definition of the two sets of requirements: the functional requirements set and the constraint requirements set. The functional requirements set (functions) are defined and the five constraint requirements types (performance, physical, operability, test and design) are examined and explained through example.

- Section 4 - Requirements Engineering Procedures.
  Provides the procedural framework for defining and analyzing the system requirements. The procedures consist of fourteen activities which are explained in the general context of the requirements engineering activities which occur. Each activity is followed by an explanation oriented toward the Conceptual and Validation Phase issues.

- Appendix A - Glossary.
  Provides definitions of the major terms used in Air Force System acquisitions and concludes with a list of acronyms and abbreviations.

SECTION 2 QUALITY REQUIREMENTS CHARACTERISTICS

2.1 Introduction

Quality requirements are dependent upon the analyst first identifying the discrete requirements of the system and then organizing these requirements in effective ways for further analysis. Initial documentation for identifying user system requirements may include early planning documents and specifications for similar systems, for system interfaces, and for existing or previously defined subsystems. In addition, documentation derived from engineering studies and prototyping or experimental test systems may be available. If the engineering activities have advanced beyond the planning and study stage, specification documents such as Type A and Type B specifications [1] may have already been developed. These early requirements documents usually have one prevailing characteristic: the system requirements are not typically distinguished (discrete) or collectively defined (well-organized).

2.2 Discrete Requirements

Figure 1 illustrates the first characteristic of quality requirements: discreteness. The key to identifying discrete requirements is to break the source documentation into individual parts which represent non-overlapping requirements. Requirements should then be categorized as functions the system must accomplish or system constraints (performance, physical, operability, test and design). At this point missing or incomplete

[1] In Air Force system acquistitions the functional specification is the system/segment specification (Type A, MIL-STD-483 (USAF), Appendix III) and the development specifications are Type B specifications. The Computer Program Configuration Item Specification (Type B5, MIL-STD-483 (USAF), Appendix VI) is the primary development specification addressed in this guidebook.

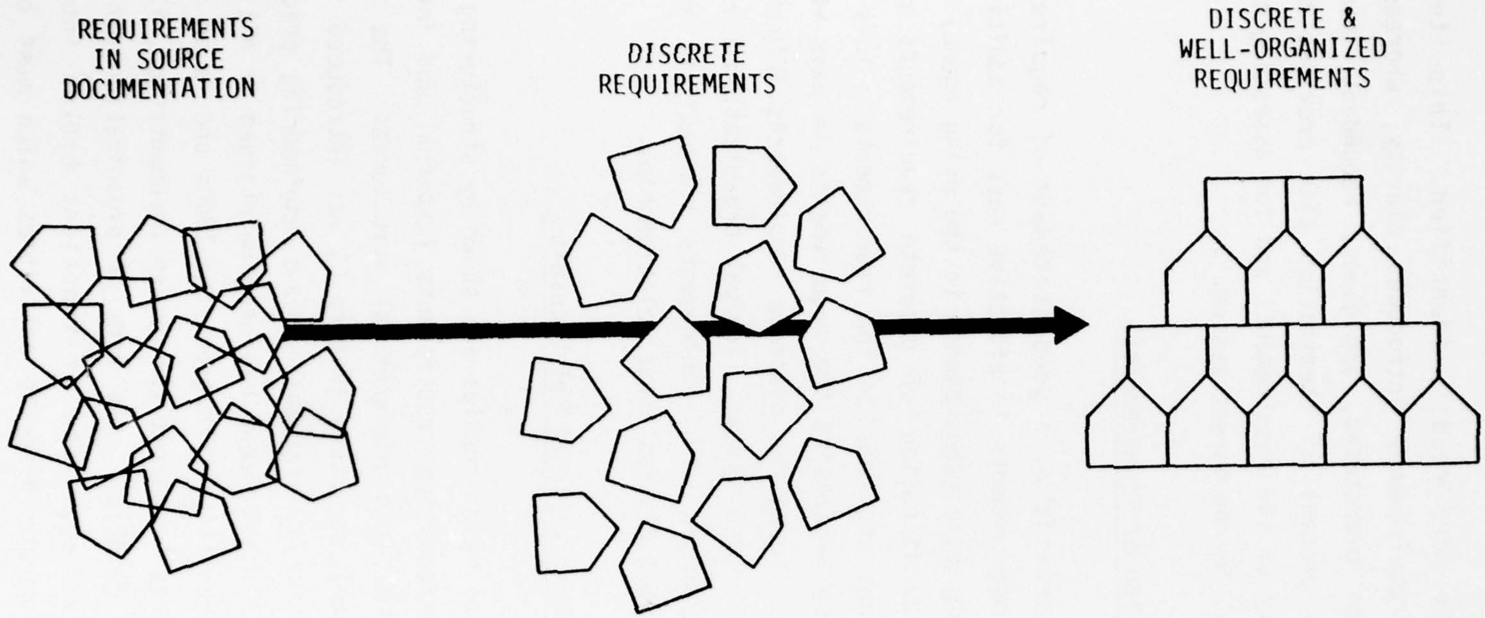


Figure 1. Development of Discrete and Well-Organized Requirements

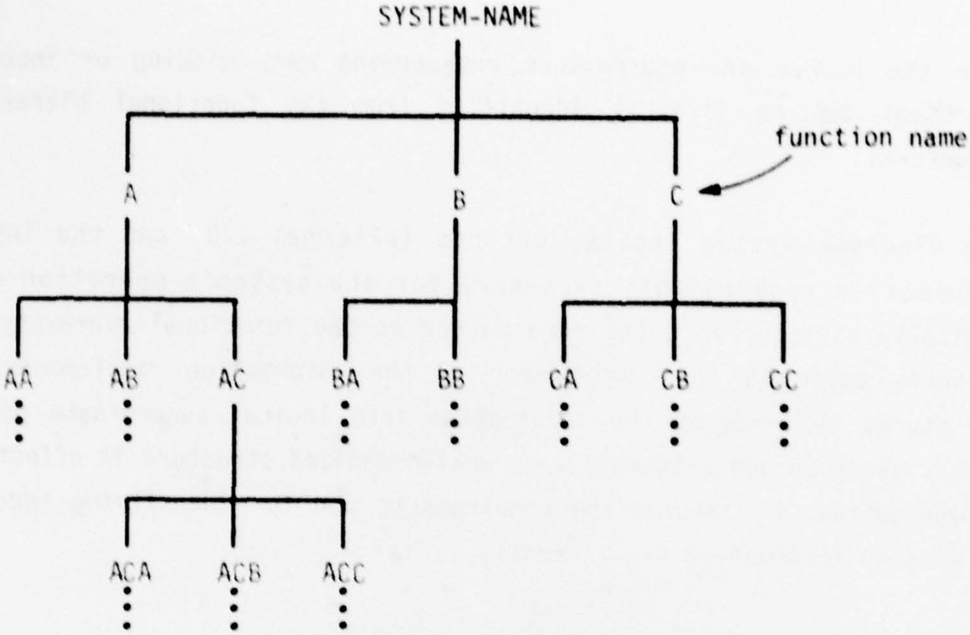
requirements can be more readily identified. This itemization and categorization of requirements introduces clarity, whereas the source documentation may be overstated, ambiguous, redundant, incomplete, and inconsistent. This process of itemization also provides the basis for verifying the quality of the requirements and for assessing the ability to test the requirements in the target system.

2.3 Organization of Requirements

The second characteristic of a good statement of requirements is the arrangement of the requirements in effective ways for additional analysis and for communicating these requirements to the using agency and to design engineers. The identification of discrete requirements provides some awareness of omissions and gaps in the requirements. This awareness is further heightened by organizing the requirements in ways which identify all the relationships among the discrete requirements (Figure 1). These relationships are of three types: logical organizational relationships, system flow relationships, and requirements traceability relationships. The following paragraphs discuss these relationships.

2.3.1 Logical Organizational Relationships

Logical organizational relationships are shown by structuring the discrete functions and the information requirements (external and internal input/output) of the system into hierarchical structures. The concept of a functional hierarchical structure (Figure 2) was introduced into military systems development through initial systems engineering practices dating back to the 1940s. This concept has been maintained in military systems development and documentation throughout the 1960s and is an integral part of the current military standards for system documentation, i.e., MIL-STD-490 and MIL-STD-483 (USAF). This form of organization provides a view of the system as an aggregate of functions broken into a logical arrangement of subordinate discrete activities which must be performed.



Graphic Representation

```
SYSTEM-NAME
  A
    AA ...
    AB ...
    AC ...
      ACA ...
      ACB ...
      ACC ...
  B
    BA ...
    BB ...
  C
    CA ...
    CB ...
    CC ...
```

Indented Representation

Figure 2. Functional Hierarchical Structure

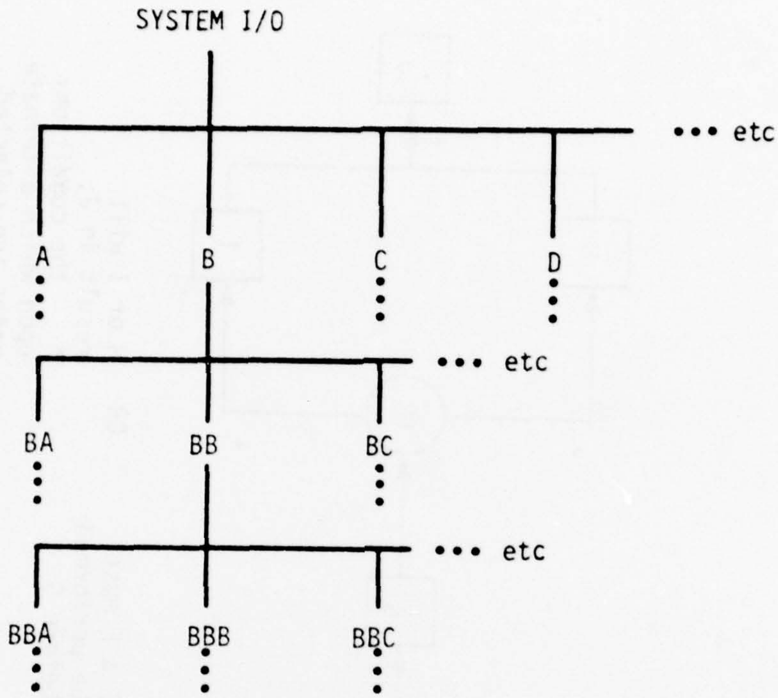
Over the course of requirements engineering many missing or incomplete functions can be directly identified from the functional hierarchical structure.

The discrete system inputs, outputs (external I/O) and the internal information requirements necessary for the system's operation can be logically structured in the same manner as the functional hierarchy. The emphasis again is the arrangement of the information requirements into structures by breaking the information into logical subordinate parts or simply as groupings (Figure 3). A well-organized structure is effective in communicating the information requirements and for identifying incomplete or missing information requirements.

2.3.2 System Flow Relationships

System flow relationships can be shown by organizing the discrete requirements in terms of control flow (Figure 4) and information flow (Figure 5). As the functions of the system are defined, the control relationships between them are identified. These control relationships describe the logical order in which the system activities should be accomplished to satisfy the system mission and operational requirements. Conditions which determine the flow direction when two or more branches occur are also represented. Control-flow analysis provides a means of viewing the system from an activity-oriented perspective and is often referred to as functional-flow analysis. As a result of this analysis the requirements are viewed in a well-organized manner and missing or incomplete functions and relationships between the functions are identified. Final control-flow documentation becomes another effective means for communicating system requirements to implementing engineers.

On the other hand, the information flow analysis (Figure 5) builds upon the I/O hierarchical structure (Figure 3) by providing a means of viewing the system as an information processing system. During this analysis the flow relationships between external system inputs and resulting outputs are



Graphic Representation

SYSTEM I/O
INPUT-A ...
OUTPUT-B
BA ...
BB
BBA ...
BBB ...
BBC ...
(etc)
BC ...
(etc)
INPUT-C ...
OUTPUT-D ...
(etc)

Indented Representation

Figure 3. I/O Hierarchical Structure

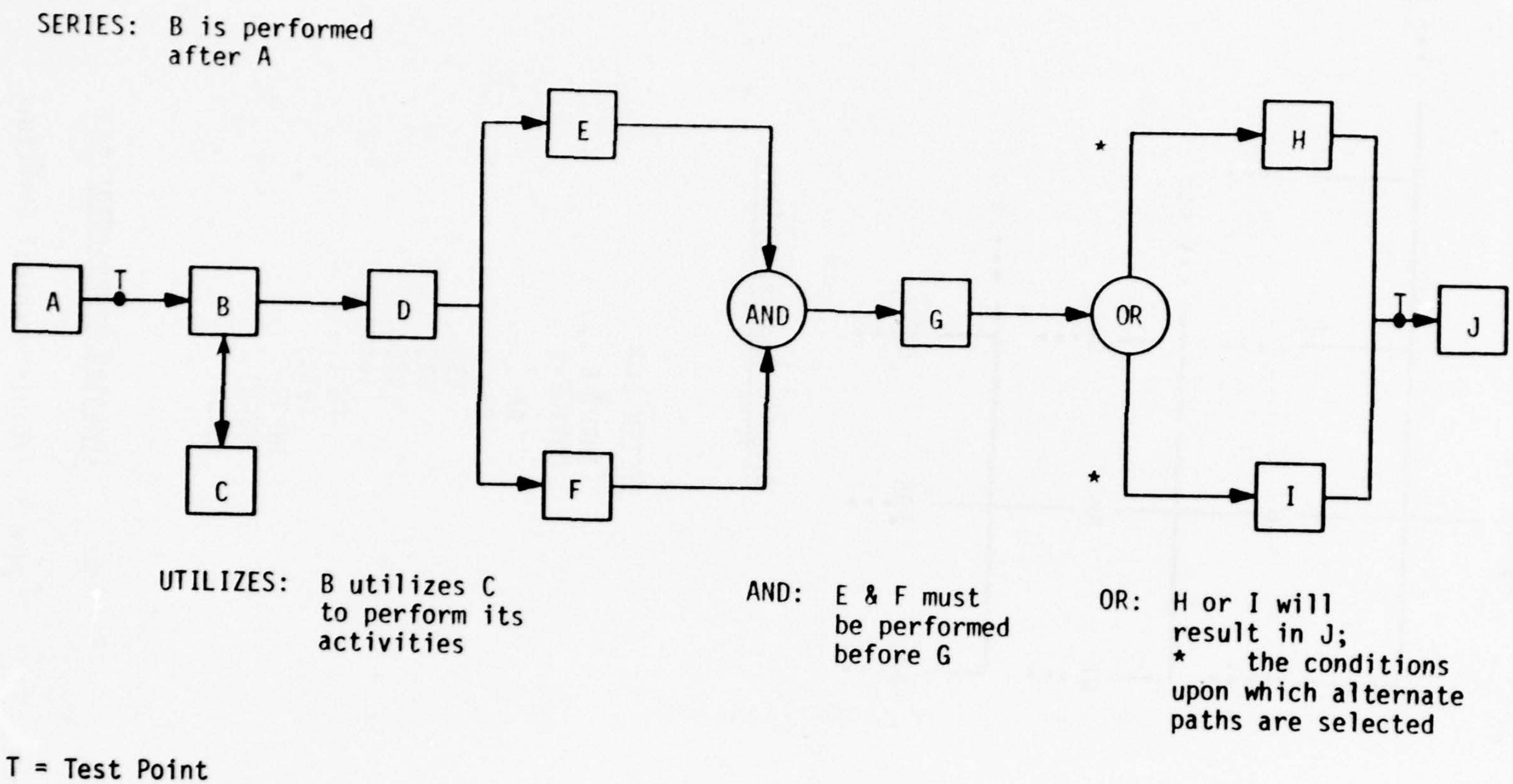


Figure 4. Control-Flow Diagram

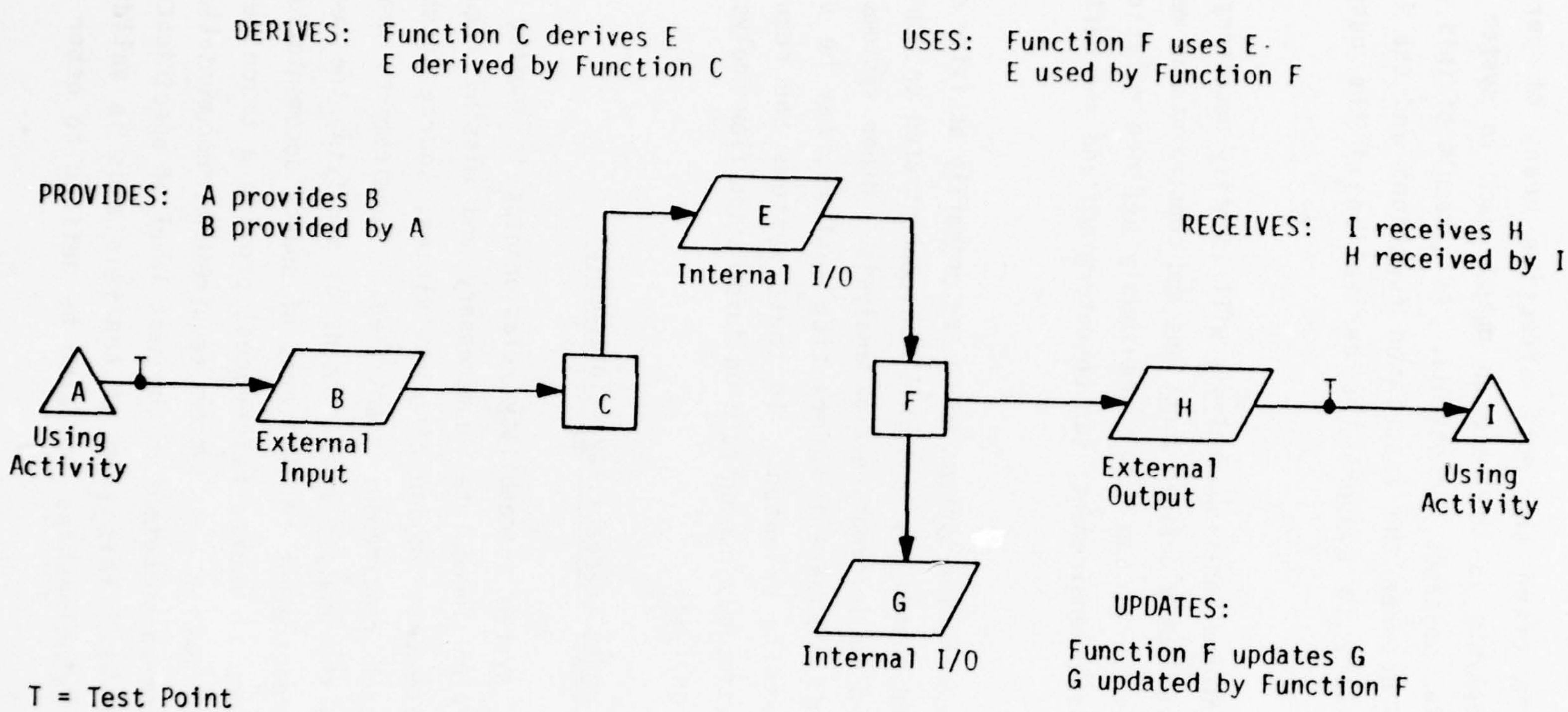


Figure 5. Information-Flow Diagram

identified. Quite often the most effective means of performing information-flow analysis is to trace an output back to system inputs, either external data, messages, or stimuli. As a result of this analysis the relationships between the associated functions and the internal information necessary to support the derivation of the output are identified.

Control-flow and information-flow analysis will identify necessary changes and additions to previously defined functions and constraints as well as to the hierarchy structures and other previously defined relationships. Missing or incomplete requirements can be determined and the deficiencies corrected.

Requirements engineering for systems which are primarily activity oriented, such as command and control systems, will be concentrated on control-flow analysis as opposed to information-flow analysis. Other systems such as communications and management information systems, may be primarily information processing oriented. In these systems the requirements engineering activities may concentrate on information-flow analysis rather than control-flow analysis.

2.3.3 Requirements Traceability Relationships

Identification of system traceability relationships is another effective means of identifying incomplete, unnecessary and missing requirements. During the requirements engineering activities, source documents are referenced for each requirement identified. Requirements traceability analysis provides the analyst with a means of verifying the requirements by linking each requirement to all forms of source documentation. These links, in the form of source references, provide a trace between the requirements from one set of system requirements documentation to the allocated requirements contained in the next level of specification; e.g., (Type A to Type B). This form of analysis aids in validating the requirements. Relationships can also be defined to other pertinent studies, analyses, and plans which are being accomplished concurrently with the requirements engineering activities, such as program management directives and plans, system sizing and timing studies, prototyping, simulations, test planning, and the like. System test requirements (quality assurance), as well as subsequent test plans, procedures, and reports, can be effectively related to the system functional-performance requirements. The links to associated system plans, analyses, and studies accomplished prior to, during and subsequent to the start of formal requirements engineering are crucial to the overall systems engineering concept. The traceability relationships also provide a bridge between requirements engineering activities and subsequent implementing engineering, since the requirements can be traced from Type A to Type B5 specifications (and other specifications) and system test plans and procedures during the later phases of the system acquisition.

Throughout the requirements engineering activities, the analyst must be able to evaluate the impact of changes to the requirements. Whatever the reason (policy, economics, study or analysis results, engineering change proposals, etc.), the analyst must be in a position to determine the ramifications of changes to the system requirements. Once the area of impact is identified in the requirements engineering products (functional and I/O hierarchies, control and information-flows, etc.) the traceability relationships provide the capability to readily identify associated impacts to the system and to trace the impacts to all other associated documentation: program directives, plans, studies and analyses, test plans, associated system specifications (Type A, Type B, etc.) and the like. The impact can be readily analyzed and the appropriate actions taken.

2.4 Summary

Discrete and well-organized requirements support the primary goal of defining the operational mission needs of the using activity while giving the analyst visibility and control over the system definition process. Discrete and well-organized requirements are prerequisites for the creation of good Type A and B specifications.

SECTION 3 SYSTEM REQUIREMENT TYPES

3.1 Introduction

The system requirement types are functional requirements, performance requirements, physical requirements, operability requirements, test requirements, and design requirements. In developing requirements or identifying system requirements from requirements documents, any combination of these requirements types may exist. Understanding the six requirement types and their use contributes significantly toward achieving quality requirements definitions. System requirements fall into two sets: the functional requirements and the constraint requirements (Table 1).

3.2 Functional Requirements Set

The functional requirements set is the backbone of the system requirements engineering process. It is within this set of requirements that the pure design-free or solution independent needs are declared. Simply stated, the functional requirements represent the total discrete system activities required to achieve a specific objective; this is most often referred to as the mission objective. A functional requirement identifies what must be accomplished without identifying any aspect concerning the means such as hardware, computer programs, personnel, facilities, or procedural data. The functional requirements represent a problem statement devoid of any overtone or specifics regarding real or conceptual solutions which satisfy any or part of the needed functions[1]. Some examples of

[1] Functions take on different meanings within three types of system documentation as required by MIL-STD-490 and MIL-STD-483 (USAF). Type A specification functions are defined for the system as a whole as defined above. Type B5 specifications define the CPCI functions to include the inputs, processing, and outputs. The Computer Program Components (CPCs) of the Type C5 specification may correspond to the functions in the Type B5 specification if the B5 requirements satisfy the computer program developer's design approach. For the purpose of requirements engineering, functions are defined to be the same as Type A specification functions. In documenting functions in Type B5 specifications, the associated inputs and outputs are included.

Table 1. System Requirement Types

SYSTEM REQUIREMENTS	FUNCTIONAL REQUIREMENTS (functions)	The set of discrete functions which identify the pure design free or solution independent needs of the system as a whole. The functional requirements identify what must be accomplished while avoiding solution statements or overtones.	
	CONSTRAINT REQUIREMENTS (Constraints)	PERFORMANCE	How well the system functions must be accomplished,such as timeliness and accuracy. Also called performance characteristics, MIL-STD-490.
		PHYSICAL	Influences the design solution in a physical manner: power, size, weight, environment, human factors, existing system interfaces, GFP, etc. Also called Physical Characteristics, MIL-STD-490.
		OPERABILITY	Reliability, maintainability, availability, dependability.
		TEST	Identify the functional, performance, physical, operability, and design requirements which will be evaluated during system integration and test.
		DESIGN	The minimum or essential design and construction requirements which are a constraint on the functional requirements of the system during the design and construction of the system end-items (CIs/ CPCIs). Also called Design and Construction, MIL-STD-490.

discrete top-level functions for an electronic system might be surveillance, tracking, identification, interceptor control, and communication.

The functional requirements are the most difficult requirements to identify. The problems arise partly from a lack of understanding of the requirement types. Without guidance, requirements engineers (government and contractor) work without a well defined and consistent set of terminology and engineering techniques for requirements engineering. The lack of requirements engineering terminology and standards allows even the best-intentioned analyst to digress from the "need" category to "how to" or solution-oriented requirement definitions. This is a natural tendency especially for any design-oriented engineer, such as a software engineer. As soon as a need is identified an immediate and more predominate solution response is quite natural. Preconceived ideas from past engineering experience or operational experience with existing systems naturally come to mind. The results are "system requirements" (functions and constraints) which are semantically riddled with solution overtones or specific design details without conscious realization or justification. The thought process simply shifts to a solution oriented position almost at the point of conceptual thought.

An example of a solution oriented statement is "...the pressure, temperature, and humidity (PTH) data shall be recorded on magnetic tape every ten (10) seconds..." In this example the basic function is a recording of PTH data, but the solution oriented feature is that the data will be recorded on magnetic tape.

3.3 Constraint Requirements Set

The second set of requirements is the constraint set which consists of five requirement types: performance, physical, operability, test, and design (Table 1). The constraint set modifies the functional requirements set.

Without the constraint set, a solution for the system functional requirements could not be achieved. Since only need is expressed in a functional requirements set, any number of solutions may be possible. In order to realize a solution, the problem identified in the functional requirements set must be constrained. However, excessive or unrealistic constraints, can eliminate all solutions or increase the technical risks and cost of the solution. Therefore, identification of the constraint requirements must be achieved with care. Whenever specific constraints are identified, there must be sufficient justification, such as an engineering analysis, which clearly shows that the constraint is reasonable, necessary, and practicable, and represents an actual requirement and not just a desirable feature. The five constraint requirement types are discussed in the following paragraphs.

3.3.1 Performance Requirements

Performance requirements identify "how well" the functions of the system must be accomplished. These requirements are the essential quantifiable statistical parameters upon which the successful accomplishment of system functions can be evaluated, such as timeliness and accuracy. The timing performance constraints include computational-solving times, countdown or event timing, and timing allocations as established through engineering analysis. An example of the performance constraints is "all displays shall be updated within 3.0 seconds after the input..."

3.3.2 Physical Requirements

Physical requirements constrain or significantly influence the design solution in a physical manner. The physical constraints include power, physical features (size and weight), environmental considerations (controlled or natural), human performance capabilities and limitations (human factors), predetermined internal and external system interfacing, use of existing equipment (off-the-shelf) and Government Furnished Property (GFP), and use of standard parts.

Power at a remote site may have to be supplied by generator or be received from utilities adjacent to the system site. If the system is airborne the power may be received from the aircraft. The power considerations may be predetermined by the situation and, therefore, constrain the solution possibilities. Again, the size and weight of equipment to be considered as part of the configuration may have to be quantitatively stated. For instance, a system which is to be installed in an existing facility, aircraft or launch vehicle would require specific weight and size requirements to be identified. Mounting location and conditions may also have to be identified. Weight and size are also important to future growth and transportability of the system components as well as installation and maintenance.

Environmental aspects are also critical physical requirements. Ranges of atmospheric pressure, temperature, and humidity (PTH) may have to be specified both in terms of the operational conditions of the system as well as non-operational conditions such as transporting the system or any of its parts which are sensitive to PTH and shock. Additional facility environmental requirements are illumination and noise levels, wind and snow and others. Human performance is identified where the design of the system should be significantly influenced by the limitations or capabilities of personnel involved with the system. Human performance requirements concern the tasks to be performed by the personnel, the time required to accomplish a task, the number of persons involved, the sustenance or life support requirements related to the tasks, training requirements, and training equipment or aids.

Other physical constraints concern predetermined interfacing with existing external or internal system components. For instance the system may be interfaced with existing communication systems such as AUTODIN or AUTOVON. Again the system may transmit or receive electromagnetic signals from other electronic devices. The system might have to interface with navigational systems. Internal interfaces are more limited in the initial requirements definition process, because their identification lends itself to the definition of the configuration items of the proposed system. However, in some proposed systems it is known very early that a particular piece of equipment must be included in the configuration and forms a part of the internal system interfaces. An example of this is deciphering equipment which the proposed system may use in order to communicate with an external system where classified information is received or transmitted.

The last two physical requirements are off-the-shelf/GFP equipment and the use of standard parts. In some systems existing equipment such as the deciphering equipment mentioned previously may be provided to the contractor for inclusion in the proposed design. Off-the-shelf equipment or GFP may be stressed to decrease risks and cost. Requirements to use standardized parts is a logistical consideration which has significant bearing on the design process. Parts control is applied more universally during the design definition process to control the selection of parts for inter- and intra- system equipment development. Parts control is more easily thought of as a program which the contractor must implement as part of his design process.

3.3.3 Operability Requirements

Operability requirements include system availability and dependability. Availability incorporates the aspects of reliability and maintainability; dependability incorporates the aspects of survivability and vulnerability (S/V) and external electromagnetic interference. Again these requirement types modify the functional requirements and constrain the problem. Each of these operability requirements categories is influenced by design related issues, policy related impact, or non-controllable factors.

Air Force Regulation 80-5 defines reliability as the probability that a part, component, subassembly, assembly, subsystem or system will perform for a specified interval under stated conditions with no malfunction or degradation that requires corrective maintenance actions. Maintainability is closely related and inseparable from reliability and is defined to be a characteristic of the design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time when the maintenance is performed using prescribed procedures and resources. Hardware reliability is usually expressed in terms of Mean Time Between Failure (MTBF) or Mean Time Between Maintenance Action (MTBM). Hardware maintainability is expressed in terms of Mean Time to Repair (MTTR). The relationship between reliability and maintainability is termed the availability of the system; this is usually expressed as a ratio between MTBF and MTTR. Reliability is not considered by many to be an appropriate term when applied to system computer programs, since certain software failures can be attributed to design deficiencies which cannot be adequately predicted and tested.

Dependability addresses the issues of system survivability and vulnerability (S/V), and external interference. Survivability is the ability of the system to achieve its mission under the conditions of a man-made hostile environment. In addition, the system may be required to operate under the conditions of interference from external electromagnetic sources (Electromagnetic Compatibility - EMC) as well as operate under threat of possible electronic countermeasures (ECM) such as spoofing and jamming.

Therefore, operability reflects many constraints upon the functional requirements set. The availability (reliability/maintainability requirements), and dependability requirements (S/V, EMC, ECM) reflect operational issues. These operability requirements are identified early in the requirements analysis activities and are expressed in the various planning documents and are reflected in specification documents for the system.

3.3.4 Test Requirements

Test requirements impact the design process and the resulting system configuration. The test requirements have been singled out from the other constraint requirements in this guidebook to emphasize the importance of the testability of the system requirements. The test and evaluation requirements are usually specific to each acquisition and will be initially identified at a high system level in early requirements documentation.

In order to test certain system requirements, a unique test must be associated with the appropriate end-item which incorporates requirement(s) to be tested. For those requirements which are inherent in a collection of end-items, the test of a requirement will be accomplished during system testing. Critical system requirements should be allocated to unique end-items, as much a possible to improve the requirements testability. Section 4 (MIL-STD-490/483 Type A and B Specifications, Quality Assurance Provisions) identifies the specific requirements for formal test and verification of the system (Type A) and subsequently its end-items (Type B). These test and verification requirements identify what specific system requirements of Section 3 of the specification must be satisfied. Test requirements, therefore, identify the functional, performance, physical, system-effectiveness, and design requirements which will be evaluated during system integration and test.

3.3.5 Design Requirements

The last form of constraints are the design requirements. These requirements represent the minimum or essential design and construction requirements which are not addressed by the four previously described constraint requirement types: the performance, physical, operability and test requirements. Like the other constraint requirements, these requirements restrain the functional requirements of the system during the design and construction of the system end-items (CIs and CPCIs). During the initial phases of systems requirements engineering (Conceptual and Validation Phases), certain design and construction standards may be specified directly or by reference to other specifications or standards. According to MIL-STD-490, the design requirements include appropriate design standards, requirements governing the use or selection of materials, parts and processing, interchangeability requirements, safety requirements, and the like. As the system development continues, engineering analysis and trade study results (as well as other engineering activities such as prototyping and simulations) may indicate the need for additional design constraints which are practicable and necessary for the system's operation and maintenance (O&M). An example of the O&M design constraint is the specification of computer programming requirements for software end-items (CPCIs): during the Conceptual Phase these design requirements are defined for the system as a whole and govern the design and construction of system functions which are implemented in software (MIL-STD-483, Appendix III).

SECTION 4 REQUIREMENTS ENGINEERING PROCEDURES

4.1 Introduction

Requirements engineering is an "iterative" process of defining the system requirements and analyzing the integrity of the requirements for completeness, consistency, testability, and traceability. As the process conti ies the system requirements are defined and analyzed in a progressively expanding manner. The definition and analysis activities will move from one area of concentration to another as the results of previous activities reveal areas needing additional work. No singular approach can be rigidly defined and applied which can take into account the many possibilities which must be considered. However, guidelines for requirements engineering and associated tasks can be defined and then tailored for specific requirements engineering applications. This section presents a general framework for requirements engineering as illustrated in Figure 6. Each block represents a unique requirements engineering activity which shall be accomplished in defining and analyzing system requirements. There is a continual interaction between the activities of each block, and although each block appears as a single activity, it is in fact part of a continuum. The selection of an actual approach for a given application is one of the tasks (BLOCK 2).

The activities identified in Figure 6 may be organized into five general steps. In step 1 (BLOCKS 1-2) pertinent source documentation is identified and reviewed. The analysis team develops a requirements engineering plan which identifies the resources required and the specific approach to be taken in performing the remaining requirements engineering tasks (BLOCKS 3-14). Step 2 involves identifying and organizing the activity structure (BLOCKS 3-5) and information structure(s) of the system (BLOCKS 6-8). The requirements engineering tasks associated with BLOCKS 3-5 are concentrated on analyzing the system source documentation in terms of activities performed by the system. If the system is primarily activity oriented, such as a command and control system, the analysis activities may be concentrated on the tasks identified in BLOCKS 3-5. If on the other hand,

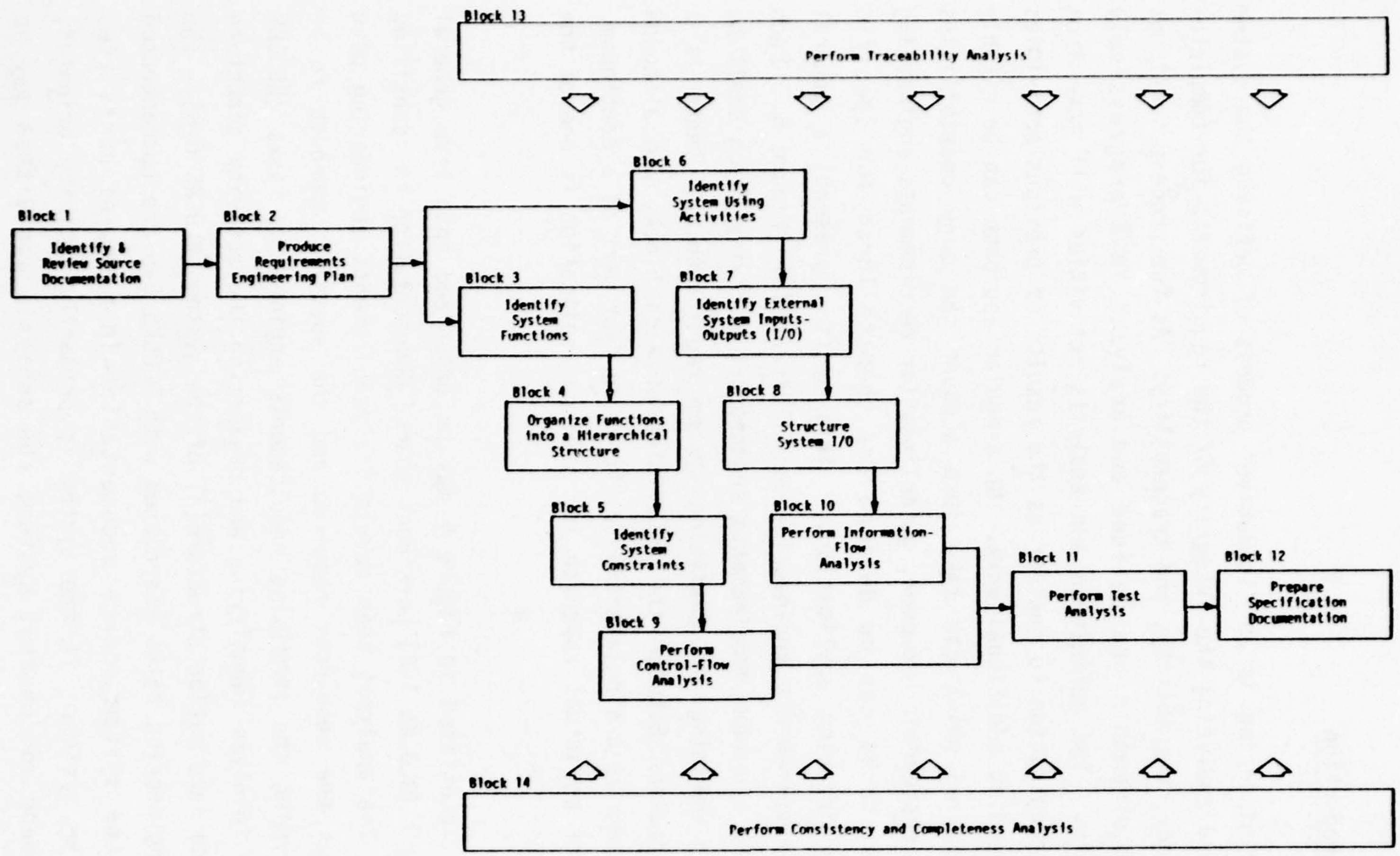


Figure 6. Requirements Engineering Procedures

the system is primarily information oriented, as in the case of a communications system or an automated data processing system (ADP) application such as a management information system, the analysis activities may be concentrated on the tasks associated with BLOCKS 6-8. The activities associated with BLOCKS 3-5 and BLOCKS 6-8 are generally done concurrently. During step 3 the flow of control between system functions (BLOCK 9) and the flow of information into, within, and out of the system (BLOCK 10) can be defined and analyzed. Step 4 involves analyzing the system requirements for testability (BLOCK 11) and preparing required specification documents (BLOCK 12). Step 5 consists of two activities which are continuously performed in conjunction with the activities of BLOCKS 3-12. Source documentation references shall be maintained for each requirement identified and traceability analysis shall be performed (BLOCK 13). Various consistency and completeness checks (BLOCK 14) shall be accomplished.

In the following paragraphs each block in Figure 6 is explained in the general context of the requirements engineering activities which occur. Following this general description is an explanation oriented to the Conceptual Phase and Validation Phase issues. The proximity of these descriptions has been chosen to communicate the subtleties between the two phases which is too often misunderstood.

4.2 Identify and Review Source Documentation (BLOCK 1)

During this task the requirements analysis team shall individually review the source documentation in order to become familiar with the overall system requirements. It may be appropriate to initiate a formal mechanism to track individual and team concerns throughout the definition and analysis activities. During the review sessions the analysis team shall perform a general evaluation of the requirement types contained in the source documentation. The review of the source documentation and the assessment of requirement types are prerequisites for developing the requirements engineering plan (BLOCK 2).

4.2.1 Conceptual Phase

The objective of the requirements engineering activities during the Conceptual Phase will be either to produce an initial system specification (Type A) from available user documentation or to determine the quality of the requirements in the initial system specification prior to the Validation Phase activities. Pertinent documentation for producing an initial system specification includes various planning and user requirements documents (PMD, PMP, ROC, SON) along with specifications for similar systems, for system interfaces, and for existing or previously defined subsystems. In addition, documentation derived from engineering studies and prototyping or experimental test systems shall be used in defining and analyzing the requirements of the system. If the engineering activities have advanced beyond the planning and study stage, the initial system specification may have already been prepared. If an initial system specification does exist, the requirements and analysis activities shall be oriented toward evaluating the system specification prior to the initiation of the Validation Phase.

4.2.2 Validation Phase

The objective of the requirements engineering activities during the Validation phase shall be (1) to refine the initial system specification (Type A) derived from the Conceptual Phase in order to authenticate and baseline the system operational requirements and/or (2) to expand and allocate the authenticated system specification requirements to system end-items (CIs/ CPCIs). The initial system specification, along with other pertinent documentation as described in the preceding paragraph, shall be used as an input to the BLOCK 1 activities in order to provide the basis for authenticating the requirements of the system. On the other hand, the authenticated system specification (Type A) shall be the input to BLOCK 1 activities leading to the allocation of requirements to system end-items (CIs and CPCIs) and the preparation of Computer Program Development Specifications (TYPE B5).

4.3 Produce Requirements Engineering Plan (BLOCK 2)

After review of the source documentation the analysis team shall determine the specific approach to accomplishing BLOCKS 3-14. This approach shall take into account all available resources including personnel, schedule, and financial considerations. The planning shall detail the methodology to be applied (tools, techniques,conventions, etc.), specific tasks to be accomplished, personnel assignments, resource descriptions, schedules and milestones, preliminary and final documentation to be produced (BLOCK 12), progress reviews and quality assurance procedures. The results shall be described in a requirements engineering plan.

If automated tools are selected to assist in the requirements definition and analysis of the source documentation, features of tool to be employed shall be determined. This selection shall insure that the analysis proceeds in a uniform manner, and the features of the automated tool satisfy the requirement types identified in the source documentation. In addition, the planning shall identify specific automated reports required during subsequent requirements definition and analysis activities and for final documentation.

4.4 Identify System Functions (BLOCK 3)

During this task the source documentation is analyzed and the system functions, necessary to control or produce the desired outputs from the available inputs, shall be identified. A function is a discrete activity within a system. The collection of discrete functions, defines the total activities which must be accomplished by the system to achieve a given objective. The functions identified shall range from high level (first possible functional breakout of the system) to detailed lower level functions which represent finite, distinct actions to be performed by system equipment, computer programs, personnel, facilities, procedural data, or combinations thereof.

The requirements definition and analysis activities associated with this task shall be oriented toward identifying the actual user functional requirements which are necessary to achieve the mission objective.

Naming a function is an important part of the requirements engineering process. Function naming conventions shall be defined (BLOCK 2) and consistently applied throughout the requirements definition and analysis activities. The following are required or recommended conventions for developing function names:

Required

- Each function shall be given a unique name conforming to the function name in the source documentation or its characteristics.

- The function name shall be succinct. This increases the ability of the reader to retain the idea being expressed, especially for large or complex systems consisting of many functions.

- The function name shall not imply any preference for a design solution, even if the source documentation specifies design detail.

Recommended

- The following function naming constructs are recommended. The use of the subject constructs should be restricted to instances where the verb constructs can not be derived:

CONSTRUCT	EXAMPLE
Verb	Boost
Verb Object*	Boost Vehicle Boost Launch Vehicle Display Fail at Ground Control Read Manual Signal into Logic Stream
Compound Verb	Recover and Evaluate

Compound Verb, Object*	Recover and Evaluate Vehicle Recover and Evaluate Launch Vehicle
Subject*	Evaluation Payload Evaluation
Compound Subject*	Recovery and Evaluation Vehicle Recovery and Evaluation Payload and Vehicle Recovery and Evaluation

* with or without modifiers, such as adjectives and/or prepositional phrases.

- The function name should be limited to 50 characters or less, including blank characters (spaces) between words in the function name.

- Abbreviations which are defined and maintained throughout the requirements engineering activities may be used in the function name.

As each function is identified and named, the primary and secondary references to the source documentation shall be maintained (BLOCK 13). Each function shall be supplemented by a description of the function and its purpose, a statement of the conditions under which the function is activated, and a description of the system external and internal inputs/outputs that the function will receive, use, or generate. The latter descriptions serve as a basis upon which the requirements engineering activities of BLOCKS 7, 9, and 10 will proceed.

4.4.1 Conceptual Phase

Prior to development of the initial system specification (Type A), the functional requirements of the system are not usually collectively defined. The analysis team shall identify the functional requirements from available source documentation and through interviews with the using agency. If an initial system specification has been prepared, the analysis team shall evaluate the functions directly from the initial system specification and the supporting documentation as described in BLOCK 1. If the source documentation is evaluated to have justifiable and well defined functions, the analysis team shall consider adopting the functional identification. The analysis team shall not be restricted to the specific function names identified in the source documentation primarily because many source documents tend to identify functional requirements in design or solution terms.

4.4.2 Validation Phase

During the Validation Phase the initial system specification (Type A) shall be analyzed and authenticated. In addition, various end-item development (Type B) specifications shall be produced (BLOCK 12). The identification of system functions leading to the authentification of the system specification shall proceed under the same guidance as described above for the Conceptual Phase. Development specifications (Type B5s) are initiated from the baselined requirements as documented in the authenticated system specification. Functional requirements in the authenticated system specification are further analyzed and refined. The analysis of system requirements leading to the Type B5 specification generation (BLOCK 12) shall be oriented toward allocating system functions identified in the authenticated system specification to specific CPCIs. As such, the allocation shall be accomplished without specific solution orientations implied by the CPCI names or the function names below the CPCI.

4.5 Organize Functions into a Hierarchical Structure (BLOCK 4)

In conjunction with identifying the system functions as described in BLOCK 3, the functions shall be arranged into logical hierarchical structures (Figure 2). This form of organization is suited for structuring system functional requirements in a logical arrangement for communicating system functions and the relationships between the functions to design engineers. This form of organization provides a view of the system as an aggregate of functions broken down into a logical arrangement of subordinate discrete activities which must be performed. This logical form of organization is distinguished from the control-flow (BLOCK 9) and information-flow (BLOCK 10) forms of organizing system functions.

The functions of the system shall be grouped into higher levels of organization representing the first possible breakout of the system. Upper-level functions shall be refined by the identification of subordinate levels. Each level of the hierarchy shall be limited to six functions or less. This limit of six functions has been shown to increase the human understanding of the system functional requirements. Should the need exist for more than six functions at a given level, the analysis team shall restructure upper levels of the hierarchical structure to resolve the problem. In a functional hierarchy the sum of the activities of the functions on a given level shall be equal to the activity at the next higher level in the hierarchy. This principle means the total system activities are defined by the functions at the lowest level in the hierarchy.

During the course of the organization of functions into a logical hierarchy, the names of previously defined functions may be altered in order to conform to the logical structuring. On the other hand, the logical structuring may necessitate the creation of pseudo-function names in order to provide a means of organizing functions under special and meaningful groupings. In addition, the hierarchical structuring may necessitate identification or creation of new functions which were omitted in the source documentation.

4.5.1 Conceptual Phase

In developing the (Type A) system specification, the upper-levels of the system functional hierarchy shall be limited to groupings which communicate system operational needs. Many system developments require that the system functions be organized into discrete segments. In this case, the system becomes the first level of the functional hierarchy and the segment become becomes the next lower level.

System functions are organized into discrete segments when the system will require the participation of several contractors and government agencies. The groupings of system functions into segments shall be accomplished only for the specific purpose of clearly defining the contractual responsibilities between the procuring agency and the contractor(s). If this is the case, the system specification functional requirements shall be allocated to various segmented specifications. Therefore, the first level breakout of the hierarchy shall represent the segment. If the allocation is justifiable (because of predetermined contractual reasons), the analysis team shall incorporate the segment organization into the second level of the system hierarchical breakout. If the segmentation is not predetermined and binding, the analysis team may restructure the segments identified in the source documentation when further analysis of the functions justifies different segmentation and lower-level functional breakdowns.

The next level (with or without segmenting) is the functional area (MIL-STD-480, 483 (USAF), and 490). An example of discrete top-level functions at a functional area level in the hierarchy for an electronic system might be surveillance, tracking, identification, interceptor control, and communications. The analysis team shall continue defining and expanding the system functional requirements into a logical organization of subordinate functions; each level shall be limited to six functions or less.

4.5.2 Validation Phase

The hierarchical organization of functions into segments and functional areas shall proceed under the same guidance as described above for the Conceptual Phase. The functions of the system specifications (or segmented specification) are further allocated to various end-items. In conjunction with this allocation, the next level below the functional area in the functional hierarchy is defined, the configuration item (CI), or in the case of Type B5 specification preparation, the Computer Program Configuration Item (CPCI).

Below the CPCI, the hierarchical structure consists of functions and any number of subordinate functions. Naturally, the definition of some branches of the hierarchy will proceed more rapidly and to a greater number of levels than others. Areas needing more study shall be identified and the structure shall be completed when conclusions resulting from the studies are available. The functional hierarchical structure shall include all the system functions.

During the course of defining, analyzing, and allocating system requirements, the analysis team shall evaluate and be guided by existing design studies and other analyses of system logistic support, system maintenance, system activation and test, and personnel and training. The functional allocation shall identify specific problem areas (i.e., technical, logistical, financial) where additional studies will be required before the allocation can proceed or be validated. All allocations shall be based upon sound engineering reasoning, since the allocation of system functions to specific physical end-items is a major system design decision. Although this allocation may be predetermined by such considerations as policy, economics, or existing system characteristics, it is essential that the analysis team review all allocations thoroughly in order to validate the technical integrity of the resulting system. Primary and secondary references to source documentation (studies, technical papers, etc.) supporting the justification of the organization of the functional hierarchy shall be maintained (BLOCK 13).

4.6 Identify System Constraints (BLOCK 5)

In conjunction with the identification of system functions and organizing functions into a hierarchical structure, the analysis team shall identify all system constraints. The constraint requirements shall be limited to performance, physical, operability and design. Test Requirement constraints are addressed under BLOCK 11. Constraint requirements shall be derived from available source documentation or from the results of trade-off studies, feasibility studies or advanced development studies. Each constraint requirement shall be related to specific function levels in the functional hierarchy. A constraint applied to a given level in the functional hierarchy implies that the constraint is applicable to each lower level function in the hierarchy. As the constraint analysis continues the constraints may be allocated to lower level functions in the functional hierarchy. Constraints which are not clearly justified from available documentation shall be eliminated from consideration until documented justification is available. All constraint requirements shall be stated in specific quantifiable parameters, either as a single value or range of values, including the unit of measure, limits, accuracy or precision, and frequency.

During the course of identifying the various constraints imposed on the functions of the system, the analysis team shall verify that no combination of constraints results in excessive or unrealistic engineering requirements (BLOCK 14). Technical risks identified by the analysis of constraints shall be followed up by additional studies to resolve areas of conflict.

Primary and secondary references to source documentation and analysis and studies which support and justify each constraint requirement shall be maintained (BLOCK 13).

4.6.1 Conceptual Phase

During the Conceptual Phase the analysis team shall identify the constraint requirements at the upper levels of the functional hierarchy, namely at the system (or segment) level and functional area level. Detailing of constraints below these first two levels shall be avoided unless specific substantiated reasons exist to address constraints at lower levels in the functional hierarchy. Over specifying constraints during initial system specification development limits the design flexibility during later phases of the system acquisition life cycle. The constraint requirements will vary with the available source documentation and the quality of engineering studies accomplished during the Conceptual Phase. System capacities and accuracies for a surveillance system might include the maximum number of intercepts, tracks, and sensors. Functions associated with information processing might include requirements for handling a specific number of messages of a particular size, and at specific frequencies.

The analysis team shall minimize constraints to requirements which can be tested (BLOCK 11). Constraints which are high development risks or which may conflict with other constraint requirements shall be examined in subsequent Conceptual Phase or Validation Phase studies to clarify possible conflicts and reduce technical, logistical and financial risks.

4.6.2 Validation Phase

The criteria described above for the Conceptual Phase shall apply. The analysis team shall eliminate all constraints which are not justified and testable from the system specification or supporting studies and analysis as part of authenticating the requirements. In the preparation of the computer program development specification (B5) requirements, the allocation of constraints shall be extended to the CPCI as well as the CPCI subordinate functions. All allocations shall result from system engineering decisions based upon development studies. The analysis team shall determine the need for additional studies to verify that the constraint requirements are realistic and within the state-of-the-art. Specific solutions to technical problems resulting from Conceptual or Validation Phase studies shall be omitted from development specification requirements (BLOCK 12). The study results shall be used only to determine that constraint requirements are realistic and testable.

4.7 Identify System Using Activities (BLOCK 6)

Using activities (organizations, operational units, or operator positions) which interact with the system shall be identified. The identification of using activities provides the basis of information-flow analysis (BLOCK 10). The identification shall include the names of using organizations identified in the source documentation or through other determinations such as human engineering studies. Lower level position names, such as specific operator positions shall be identified and described to the level of detail required for the associated functions.

Using activities are a form of design constraint but are separately presented in this guidebook in order to support other requirements engineering activities such as information-flow analysis (BLOCK 10). Whenever using activities are identified, there must be sufficient justification, such as engineering analysis, which clearly shows that the using activity is necessary and represents an absolute requirement and not just a desirable feature.

4.7.1 Conceptual Phase

The organizations, operational units, and positions during the Conceptual Phase shall be described for the upper levels of the functional hierarchy and shall concentrate upon describing the interaction of the using activities with the system as a whole. The specific names of the organization, operational units, and positions shall be determined from the source documentation, interviews with the using activity, and through associated studies and analyses, i.e. human engineering studies and man-machine task analysis. The personnel position descriptions shall include the duties of personnel, and the numbers to operate, maintain and control the system.

4.7.2 Validation Phase

During the Validation Phase the organizations, operational units, and positions shall be further refined and allocated to lower level functions, i.e. CPCIs and functions below the CPCI. Human performance requirements relative to the specific positions shall be considered as constraints upon the associated functions. For instance, minimum response times for human decision making, maximum time for response, etc., shall be identified. Subsequently, BLOCK 5 shall be repeated to define the human factor constraints and associate them with the proper functions.

4.8 Identify External System Inputs-Outputs (BLOCK 7)

In conjunction with identifying the using activities, the analysis team shall identify the output (responses) required from the system. Output information consists of system messages and reports necessary for the operation, maintenance, control of the system and support of the mission objectives.

Subsequent to each output being defined, the associated system inputs (stimuli) shall be identified. The input information may be used directly from the external source or used by the system (see BLOCK 10) to derive all or part of an output. Inputs and outputs shall be associated with their respective sources or destinations. These sources and destinations may be the using activities or external systems. Additional informational requirements, such as internal information necessary for the system's operation, shall be identified during BLOCK 10.

Each input or output (I/O) shall be given a unique name conforming to the I/O name in the source documentation or its characteristics. The I/O naming convention shall be consistent throughout the requirements engineering process and shall be defined during the requirements engineering planning activities (BLOCK 2). Parts of an input or output shall be identified and named as the requirements engineering process continues. Primary and secondary references to source documentation and analysis and studies which identifies the need for the I/O shall be maintained (BLOCK 13). Each I/O shall be supplemented by a description of the I/O and its purpose.

4.8.1 Conceptual Phase

The inputs and outputs defined during the Conceptual Phase shall concentrate upon the upper levels of the functional hierarchy. The emphasis shall be upon identifying specific output requirements necessary for the operational use of the system to achieve mission objectives. Output message formats shall be specified to a level which can support additional analysis of information processing resource requirements during the Validation Phase. Specific outputs such as message formats shall be described by type, format or size, and frequency. The level of detail may vary according to the system or system segment being defined. Early in the definition it may only be possible to define the existence or general nature of the outputs and inputs. Inputs and outputs to other systems or system segments shall be precisely defined.

4.8.2 Validation Phase

During the Validation Phase the outputs and inputs described in the authenticated system specification shall be expanded and refined if not completed during the Conceptual Phase. As a result of sizing and timing estimates, the output and input requirements shall be associated with specific CPCIs and functions below the CPCI. Quantitative parameters shall be described for all inputs and outputs including units of measure, accuracy, the precision requirements, and frequency. All I/O must be defined completely by the end of the Validation Phase.

4.9 Structure System Inputs-Outputs (BLOCK 8)

Concurrent with BLOCK 6 and 7 activities, the system inputs and outputs (I/O) shall be arranged into hiearchical structures (Figure 3). The emphasis on the I/O hierarchical structures is to organize the I/O and their subordinate parts into logical organizations or simply as groupings of information. Structuring the I/O is an effective means of identifying incomplete or missing I/O requirements and for communicating the input and output requirements to design engineers.

Parts of I/O identified during BLOCK 7 shall be associated with other I/O and organized into hierarchical structures. Changes and additions to the I/O hierarchical structures may be required as information-flow analysis (BLOCK 10) is accomplished. The upper parts of the individual I/O hierarchical structures shall be equivalent to the aggregate of the subordinate parts in the hierarchy. During the course of organizing the I/O into a hierarchy, the names of previously defined I/O may be altered in order to conform to the logical information structure being defined. On the other hand, the hierarchical structuring may necessitate the creation of pseudo input/output names in order to provide an effective means of organizing the I/O hierarchical structures in special and meaningful groupings. In addition, the hierarchical structuring may necessitate the identification or creation of new I/O requirements which were omitted during earlier requirements engineering activities or from the source documentation.

4.10 Perform Control-Flow Analysis (BLOCK 9)

After the functions of the system are identified (BLOCK 3), the control flow between the functions shall be described in control-flow diagrams. Control-flow analysis provides a means of viewing the system from an activity-oriented perspective and is often referred to as functional-flow analysis. The control-flow diagrams (Figure 4) shall describe the sequential flow between system functions. The control-flow diagrams shall indicate only the relationship between system functions and shall not imply any lapse in time or intermediate activity. Conditions which determine the flow directions shall be described using the following control-flow relationships as illustrated in Figure 4:

SERIES — This is a sequential relationship between two or more activities. This relationship is assumed unless an AND, OR, or UTILIZE relationship is indicated in the flow path.

AND — Activities preceding the AND must be accomplished before the flow may continue.

OR — Any one of the alternate paths may lead to the next activity. The conditions upon which the alternate paths are selected are associated with the OR.

UTILIZES — This relationship indicates that a function on a path is dependent upon the use of one or more other functions in order to accomplish its activities. A single function or sequence of functions may be defined once and utilized as frequently as necessary in the control flow without having to be redefined (replicated) for each use.

The control flow shall be restricted to concepts backed by system engineering studies or the like which clearly resolve any uncertainty of technical risks associated with the flow concept described. Where uncertainty exists the relationships shall be described as tentative or not completed, as appropriate, until subsequent analysis resolves the uncertainty. As the control flow is identified, the primary and secondary references to the source documentation shall be maintained (BLOCK 13).

Control-flow analysis will necessitate changes and additions to previously defined functions, constraints, and I/O, as well as the hierarchy structures and other previously defined relationships. Missing or incomplete requirements shall be determined and the deficiencies shall be corrected.

4.10.1 Conceptual Phase

During the Conceptual Phase the control-flow analysis shall be concentrated upon describing the sequential flow (SERIES) between the functions of the system. Conditions (AND, OR, UTILIZES) which determine the flow direction shall be described when appropriate to the Conceptual Phase analyses performed. If an initial system specification has been prepared, the analysis team shall evaluate the control-flow relationships contained in the initial system specification and the other supporting documentation. The control flow at the upper levels of the functional hierarchy shall be addressed initially. As the functional hierarchy evolves, analysis of the control relationships allocated to lower level functions shall be accomplished. As a result, the control-flow relationships shall be described for all lower level functions identified during the Conceptual Phase. The uncertainties in the control flow which are not resolved in the Conceptual Phase shall be resolved during the Validation Phase.

4.10.2 Validation Phase

The control-flow relationships in the system specification developed during the Conceptual Phase are further analyzed and refined during the Validation Phase. The control-flow analysis leading to the authenticated system specification shall proceed under the same guidance as described above for the Conceptual Phase. Control-flow analysis shall continue from the baselined requirements as documented in the authenticated system specification. The control-flow relationships in the authenticated system specification are further analyzed and refined. The Type B5 control-flow analysis shall be oriented toward defining the control flow between CPCIs and between functions within CPCIs. The control-flow description shall be expanded as the system functional hierarchy evolves. The Validation Phase control-flow description shall include all four conditions (SERIES, AND, OR, UTILIZES) which determine the flow direction as appropriate. All control-flow relationships shall be completed by the end of the Validation Phase.

4.11 Perform Information-Flow Analysis (BLOCK 10)

This activity builds upon the I/O hierarchical structure (BLOCK 8) by providing a means of analyzing the system as an information processing system (Figure 5). During this analysis, the flow relationships between external system inputs and resulting outputs shall be identified in information-flow diagrams. These diagrams provide the basis for determining that each I/O is used, derived, or updated. An effective means of information-flow analysis is to trace an output back to the system input: external data, messages, or stimuli. This method permits the relationships between associated functions and the internal information necessary to support the derivation of the output to be identified. The flow associations between system information shall be described using the following information-flow relationships as illustrated in Figure 5:

USES — This relationship indicates that a function on the path uses external information (external input) or internal system information (internal input) in order to accomplish its activities.

DERIVES — This relationship indicates that a function on the path derives either external information (external output) or internal system information (internal output) as part of its activities.

UPDATES — This relationship indicates that a function on the path updates internal system information as part of its activities.

The information flow shall indicate the relationship between system functions and system information (external and internal system I/O) and shall not imply any lapse in time or intermediate I/O being used, derived, or updated. These relationships shall be identified for each level in the information hierarchy. As the information analysis continues the relationships shall be allocated to lower levels in the information hierarchy as the I/O is identified (BLOCK 7) and structured (BLOCK 8).

For the purpose of information-flow analysis, the using activities identified during BLOCK 6 are integral to the definition of the system as an aggregate of hardware, computer programs, personnel, facilities, and procedural data. The relationships between the using activities shall be described using the following information-flow relationships as illustrated in Figure 5:

PROVIDES This relationship indicates that a using activity is the source of the external input.

RECEIVES This relationship indicates that a using activity is the recipient of the external output.

The information flow shall be restricted to concepts backed by system engineering studies or the like which clearly resolve any uncertainty or technical risks associated with the flow concept described. Where uncertainty exists the relationships shall be described as tentative or not completed as appropriate until subsequent analysis resolves the uncertainty. As the information flow is identified, the primary and secondary references to the source documentation shall be maintained (BLOCK 13).

Information-flow analysis will necessitate changes and additions to previously defined functions, constraints, and I/O as well as the hierarchy structures and other previously defined relationships. Missing or incomplete requirements shall be determined and the deficiencies shall be corrected.

4.11.1 Conceptual Phase

During the Conceptual Phase the information-flow analysis shall be concentrated upon describing the information flow between system internal and external I/O and associated functions (PROVIDES, RECEIVES). Other information-flow relationships (USES, DERIVES, UPDATES) which describe the system internal information flow shall be described when appropriate to the Conceptual Phase analyses performed. If an initial system specification has been prepared, the analysis team shall evaluate the information-flow relationships contained in the initial system specification and other supporting documentation. The information flow at the uper levels of the information hierarchy shall be addressed initially. As the information hierarchy evolves, the information-flow relationships shall be allocated to appropriate lower levels in the information hierarchy. As a result, the information-flow relationships shall be described for all lower level internal and external I/O and associated functions identified during the Conceptual Phase. The uncertainties in the information flow which are not resolved in the Conceptual Phase shall be resolved during the Validation Phase.

4.11.2 Validation Phase

The information-flow relationships in the system specification developed during the Conceptual Phase are further analyzed and refined during the Validation Phase. The information-flow analysis leading to the authenticated system specification shall proceed under the same guidance as described above for the Conceptual Phase. The Type B5 information-flow analysis shall continue from the baselined requirements as documented in the authenticated system specification. The information-flow relationships in the authenticated system specification are further analyzed and refined. The information-flow analysis leading to Type B5 specification generation (BLOCK 12) shall be oriented toward defining the information flow between CPCIs and functions within CPCIs. The information-flow description shall be expanded as the system information hierarchy evolves. All information-flow relationships shall be completed by the end of the Validation Phase.

4.12 Perform Test Analysis (BLOCK 11)

Test requirements identify the system requirements which will be evaluated during system integration and test. The principle objective of test analysis is to identify which areas in the system definition shall undergo formal test and verification. This is achieved by identifying test points on the control-flow and information-flow paths (Figures 4 and 5). As the control flows and information flows evolve, the analysis team shall determine test points on the flow paths. These test points shall be added to the flow paths at the selected test data sampling locations. The selection of test points shall be accomplished concurrent with the test planning activities. As test cases are determined by analysis of the control and information flows, the test points shall be described and associated with test plans and procedures.

The association between system test plans, analyses, and studies documented prior to, during, and subsequent to the start of formal requirements engineering is crucial to the overall requirements engineering concept. Documented test objectives preceding formal requirements engineering shall be analyzed. As a result, test points in the control and information flows shall be selected which provide data for various test cases which support testing objectives. Test analysis will necessitate changes and additions to previously defined system requirements definitions (functions, constraints, I/O, hierarchy structures, control and information flows, and associated relationships) in order to satisfy test objectives. Primary and secondary references shall be maintained between the test points and associated test plans and other supporting documentation (BLOCK 13).

4.12.1 Conceptual Phase

Before the development of the initial system specification, test objectives may be identified in various early planning documents, analyses, and studies. Concurrent with the development of the initial system specification the Test and Evaluation Master Plan (TEMP) is prepared. The TEMP documents the overall test philosophy, testing concepts, subsystem and system test objectives, and the basic test planning information. The TEMP and the quality assurance section of the system specification (MIL-STD-490/483 (USAF), Type A, System/Segment Specification) are the principle test planning requirements developed during the Conceptual Phase.

Prior to the development of the initial system specification and TEMP, the analysis team shall analyze the test objectives which are stated in various planning documents, analyses, and studies. Test points shall be determined and associated with Conceptual Phase control flows and information flows. The resulting analyses and test point determinations may require changes to the requirements definition as previously described. The preparation of the initial system specification quality assurance provisions (BLOCK 12) and TEMP shall proceed from the test point determinations and analysis activities performed during the Conceptual Phase test analysis.

If an initial system specification and TEMP have been prepared, the analysis team shall evaluate the test objectives and requirements of these additional documents along with associated early planning documents, analyses, and studies. As the test points and test cases are determined the quality assurance provisions of the system specification may require clarification and refinement. Subsequent to the authentification of the system specification, the quality assurance provisions shall be required and therefore reflected in the contractor test plans and procedures.

4.12.2 Validation Phase

Test points in the system specification developed during the Conceptual Phase shall be further analyzed and refined as the control and information flows evolve during the Validation Phase. The test analysis leading to the authenticated system specification shall proceed under the same guidance as described above for the Conceptual Phase. Validation Phase test analysis leading to the generation of development specifications (Type B5s) shall be based upon Conceptual Phase test analyses. The Conceptual Phase test points shall be further refined and allocated to Validation Phase control and information flows. If test points were not identified during the Conceptual Phase activities, the analysis team shall identify test points for Validation Phase control and information flows in the same manner as described for the Conceptual Phase. The test points shall continue to be refined as the control and information flows evolve during the Validation Phase. All test points shall be described by the conclusion of the Validation Phase and integrated into the evolving quality assurance section of development specifications (MIL-STD-490/483 (USAF), Type B5) and associated test plans and procedures.

4.13 Prepare Specification Documentation (BLOCK 12)

The preparation of specification documents shall be accomplished in accordance with MIL-STD-490 as supplemented by MIL-STD-483 (USAF). Specifications serve to document the system requirements throughout the system acquisition life cycle. In Air Force acquisitions these documents are an integral part of the management concept: configuration management, data management, system integration and testing, and contracting.

The system requirements definition and analysis activities (BLOCKS 3-11) provide the basis upon which the preparation of specification documents shall proceed. The products of BLOCKS 3-11 (functional hierarchical structures, I/O hierarchical structures, control flows, information flows, etc.) shall be incorporated directly into the specification documents in accordance with the prescribed format of MIL-STD-490/483. Additional specification document inputs (text, etc.) may be required to complete the document, however, the additions shall not conflict with the requirements engineering products previously produced. All requirements in the specification documents shall be traceable to the products of the requirements engineering performed as described in BLOCKS 3-11. Therefore, each specification document shall be cross-referenced to the requirements engineering products (BLOCKS 3-11).

Where the specification document paragraphs require additional text to satisfy MIL-STD-490/483 (USAF) specification preparation requirements, the text shall be direct and succinct. The text shall be free of vague and ambiguous terms. The text shall use the simplest words and phrases which convey the intended meaning. System requirements shall be complete, whether by direct statements or references to other documents, such as the requirements engineering products (BLOCKS 3-11) or other documents as identified and maintained (BLOCK 13). Consistency in terminology and the organization of material will contribute to the specification document's clarity and usefulness. The intent of the text is to provide supplemental understanding of the requirements identified and analyzed previously. As such the style of writing shall emphasize short and concise sentence structure. Well-written sentences shall be required with a minimum of punctuation. Punctuation shall be used to aid reading and prevent misunderstandings. When extensive punctuation is required for clarity, the sentence shall be restructured to eliminate the deficiency. The emphasis shall be upon short and concise sentences and the elimination of compound clauses. Additional style, format and general instructions for preparation of specification documents shall be accomplished as described in MIL-STD-490, paragraph 3.2.

Care shall be taken to ensure that the supplemental text statements do not conflict with previously defined system requirements (BLOCKS 3-11). Where conflicts arise, the previous requirements definitions and analysis shall take precedence, the conflicts in the supplemental text shall be removed. Reaccomplishing previous tasks (BLOCKS 3-11) may be necessary where conflicts indicate deficiencies in products developed during earlier system definition and analysis. The notes section of each specification document (Section 6, Notes) shall be used for background information or rationale which may be of assistance in understanding the requirements or specification itself.

4.13.1 Conceptual Phase

Air Force System Specifications are prepared in accordance with MIL-STD-490, Appendix I (Type A, System Specification) as supplemented by MIL-STD-483 (USAF), Appendix III (System Specification/System Segment Specification). If the requirements engineering activities (BLOCKS 1-11) have been accomplished prior to the development of an initial system specification, the initial system specification shall be developed as described in 4.13.

If an initial system specification has been prepared, the requirements engineering activities (BLOCKS 1-11) shall be accomplished and a new system specification shall be prepared as described in 4.13. The resulting system specification shall be the basis upon which the Validation Phase is initiated. Table 2 provides a cross reference between the requirements engineering activities described in this guidebook and the associated paragraph requirements in MIL-STD-490/483 (USAF) for Type A, System Specifications.

4.13.2 Validation Phase

If an initial system specification has been prepared but has not been authenticated, the requirements engineering activities shall be accomplished (BLOCKS 3-11) and a new system specification shall be generated as described in 4.13. The new generated system specification may become the authenticated system specification if contractually required by the procuring activity. Again, Table 2 provides a cross reference between the requirements engineering activities described in this standard and the associated paragraph requirements in MIL-STD-490/483 (USAF) for Type A, System Specifications. The preparation of Computer Program Development Specifications during the Validation Phase shall be done in accordance with MIL-STD-490, Appendix VI (Type B5, Computer Program Development Specification) as supplemented by MIL-STD-483 (USAF), Appendix VI (Type B5, Computer Program Configuration Item Specification). Table 3 provides a cross reference between the requirements engineering activities described in this guidebook and the associated paragraph requirements in MIL-STD-490/483 (USAF) appendices for Type B5 specification preparation.

4.14 <u>Perform Traceability Analysis (BLOCK 13)</u>

System requirements traceability is another effective means of identifying incomplete or missing requirements. Traceability gives the analyst a means of verifying the requirements by linking each requirement to the varying forms of source documentation such as program directives and plans, studies, analyses, test plans, associated specifications (Type A, B, etc.) and the

Table 2. Cross Reference between System Specification (Type A) Documentation and Requirements Engineering Activities

	MIL-STD-490/483 (USAF) Paragraphs		Requirements Engineering Activities (BLOCKS)
Section 1.	Scope		
Section 2.	Applicable Documents		1,13
Section 3.	Requirements		
	3.1	System Definition	3,4
	3.1.1	General Description	4
	3.1.2	Missions	3-10
	3.1.3	Threat	
	3.1.4	System Diagrams	4,9,11
	3.1.5	Interface Definition	3-10
	3.1.6	Government Furnished Property List	5
	3.1.7	Operational and Organizational Concepts	6
	3.2	Characteristics	
	3.2.1	Performance Characteristics	5
	3.2.2	Physical Characteristics	5
	3.2.3	Reliability	5
	3.2.4	Maintainability	5
	3.2.5	Availability	5
	3.2.6	System Effectiveness Models	5
	3.2.7	Environmental Conditions	5
	3.2.8	Nuclear Control Requirements	5
	3.3	Design and Construction	5
	3.3.1	Materials, Processes, and Parts	5
	3.3.2	Electromagnetic Radiation	5
	3.3.3	Nameplates and Product Markings	5
	3.3.4	Workmanship	5
	3.3.5	Interchangeability	5
	3.3.6	Safety	5
	3.3.7	Human Performance/Human Engineering	5
	3.3.8	Computer Programming	5
	3.4	Documentation	1,13
	3.5	Logistics	
	3.5.1	Maintenance	5
	3.5.2	Supply	5
	3.5.3	Facility and Facility Equipment	5
	3.6	Personnel and Training	
	3.6.1	Personnel	5
	3.6.2	Training	5
	3.7	Functional Area Characteristics	3-10
	3.8	Precedence	3-10
Section 4.	Quality Assurance Provisions		11,13
	4.1	General	11,13
	4.1.1	Responsibility for Tests	11,13
	4.1.2	Special Tests and Examinations	11,13
	4.2	Quality Conformance Inspections	11,13
Section 5.	Preparation for Delivery		5
Section 6.	Notes		1,3-11,13
Section 10.	Appendices		1,3-11,13

Table 3. Cross Reference between Computer Program Development Specification (Type B5) Documentation and Requirements Engineering Activities

	MIL-STD-490/483 (USAF) Paragraphs		Requirements Engineering Activities (BLOCKS)
Section 1.	Scope		
	1.1	Identification	
	1.2	Functional Summary	3
Section 2.	Applicable Documents		1,13
Section 3.	Requirements		
	3.1	Computer Program Definition	
	3.1.1	Interface Requirements	3-10
	3.1.1.1	Interface Block Diagram	3-10
	3.1.1.2	Detailed Interface Definition	3-10
	3.2	Detailed Functional Requirements	3,4,9,11
	3.2X	Function X	3,4,9
	3.2.X.1	Inputs	6,7,8,9,10
	3.2.X.2	Processing	3,4,5,9
	3.2.X.3	Outputs	6,7,8,9,10
	3.2.n	Special Requirements	5,11
	3.2.n.1	Human Performance	5
	3.2.n.2	Government-Furnished Property List	5
	3.3	Adaptation	6,7,8,10
	3.3.1	General Environment	5
	3.3.2	System Parameters	5
	3.3.3	System Capacities	5
Section 4.	Quality Assurance Provisions		
	4.1	Introduction	11
	4.1.1	Category I Test	11
	4.1.2	Computer Programming Test and Evaluation	11
	4.1.3	Preliminary Qualification Tests	11
	4.1.4	Formal Qualification Tests	11
	4.1.5	Category II System Test Program	11
	4.2	Test Requirements	11
	4.3	Acceptance Test Requirements	11
Section 5.	Preparation for Delivery		5
Section 6.	Notes		1,3-11,13
Section 10.	Appendices		1,3-11,13

like. Throughout the requirements engineering activities the need exists for the analyst to be able to evaluate the impact of changes and additions to the requirements. Whatever the reason (policy, economics, study or analysis results, engineering change proposals, etc.) traceability provides the capability to readily identify associated impacts to the system definition as well as to trace the impacts to all other associated documentation. Requirement change impacts can be readily analyzed and the appropriate actions taken. The trace links to associated plans, analyses, studies, and specifications accomplished prior to, during, and subsequent to the start of formal requirements engineering are crucial to the integrity of the requirements definition process.

Throughout the requirements engineering activities (BLOCKS 3-11), each requirement shall be associated with the sources of the requirement (source documents). These source references shall relate the system requirements to all associated specifications, studies, analyses, plans, Types A, B, and C specifications, program management directives and plans, system sizing and timing studies, prototyping, simulations, test planning, and the like. Two forms of references shall be provided: primary and secondary source references. Primary source references refer to specific paragraphs in source documentation which are the origin of the requirement. Secondary source references refer to specific paragraphs in the source documentation which provide information about closely related requirements, discussions of the rationale about the requirement or other useful background information.

4.15 Perform Consistency and Completeness Analysis (BLOCK 14)

Throughout the requirements engineering activities (BLOCKS 3-13) analysis of the consistency and completeness of the requirements definition assures the integrity of the system being defined. Associated with each requirements engineering activity are various consistency and completeness checks which shall be performed concurrent with each block:

4.15.1 Identify System Functions: Block 3

- Are all functions defined in operational terms as opposed to solution oriented terminology such as data processing terms? Remove or rename all functions which imply "how-to".

- Are the functions backed by studies or the like which resolve technical risks? Remove all functions which are not feasible or analyze the risks and resolve any uncertainty.

- Are all source references identified for each function?

- Have high level functions been broken down into lower level functions?

- Can any functions be consolidated? Can duplicated or similar functions be eliminated or consolidated?

4.15.2 Organize Functions into a Hierarchical Structure: Block 4

- Does the hierarchical structure contain all functions defined?

- Have all source references supporting the functional hierarchy been identified?

- Does the sum of the activities of each group of lower level functions represent the activities of the function at the next higher level in the functional hierarchy? Are there any missing lower level functions?

- Does each level of the functional hierarchy structure consist of six functions or less? If not, restructure the hierarchy.

- Does the hierarchy of functions contain all supporting functions which are necessary for the operation of the system?

4.15.3 Identify System Constraints: Block 5

- Have all constraints been associated with specific function levels in the functional hierarchy?

- Do constraints have source documentation references? Each constraint shall be backed by documentation which provides the rationale, or feasibility for the constraint. If no source reference is identified or available the constraint shall be eliminated.

- Do any combinations of constraint requirements imposed on the functions result in excessive or unrealistic engineering requirements, thereby increasing costs technical and schedule risks during the acquisition life cycle? Where uncertainty or conflicts exist, further analysis shall be performed. As a result the conflicts shall be removed by eliminating or adjusting the conflicting requirements.

- Is each constraint requirement defined in quantifiable terms: single values or range of values, including units of measure, limits, accuracy or precision, and frequency?

- Have constraints been overspecified? Excessive constraints eliminate design flexibility.

- Are constraint requirements applied to the appropriate functions?

4.15.4 Identify System Using Activities: Block 6

- Have all using activities (organizations, operational units, or positions) been identified and related to associated inputs and outputs?

- Have all using activity source references been identified?

4.15.5 Identify External System Inputs-Outputs: Block 7

- Have all external system Inputs and Outputs been identified?

- Have all required external I/O formats (messages, etc.) been identified?

- Are all external I/O associated with using activities (BLOCK 6) and functions (BLOCK 10)?

- Are all external I/O source document references identified?

4.15.6 Structure System Inputs-Outputs: Block 8

- Does the information hierarchy structure contain all I/O as described in the source documentation?
- Does the sum of the I/O at a given level represent the total contents of the I/O at the next higher level in the hierarchy?
- Do the I/O structures represent the contents of required messages, etc.?

4.15.7 Perform Control-Flow Analysis: Block 9

- Is there a control-flow sequence defined for every function?
- Is each control-flow sequence complete and logically correct? No lapse in time or intermediate activity shall be implied between functions in the control-flow sequence.
- Are all conditions which determine the flow direction described using the control-flow relationships (SERIES, AND, OR, and UTILIZE)?
- Are Conceptual Phase control flows primarily SERIES flows?
- Is each control-flow sequence referenced to source documentation which establishes the need and rationale for the control-flow sequence as well as resolves any uncertainty of technical risks?
- Are all control flows complete at the conclusion of the Validation Phase?

4.15.8 Perform Information-Flow Analysis: Block 10

- Is there an information-flow sequence defined for every external output desired? Can every external output be traced to inputs?
- Is every external input and output used?

- Is each information-flow sequence complete and logically correct? The information flow shall indicate only the relationship between system functions and system information (external and internal system I/O) and shall not imply any lapse in time or intermediate I/O being used, derived, or updated.

- Are all information-flow relationships (USES, DERIVES, UPDATES, PROVIDES, and RECEIVES) described as appropriate in each information-flow sequence?

- Are all using activities (BLOCK 6) associated with system external I/O?

- Is each information-flow sequence referenced to source documentation which establishes the need for the information-flow sequence as well as resolves any uncertainty or technical risks?

4.15.9 Perform Test Analysis: Block 11

- Are all test points identified?

- Are the test point source references (TEMP, Test Cases, Test Plans and Procedures, Quality Assurance Provisions of specifications, etc.) identified?

- Are test points allocated to control and information flows which are appropriate to the system definition being described, documented, and tested?

- Have all test points been identified at the conclusion of the Validation Phase?

4.15.10 Prepare Specification Documentation: Block 12

- Have all requirements defined during BLOCK 3-11 been incorporated into the appropriate specification paragraphs as described in Tables 2 and 3?

- Has supplemental text been restricted and concisely written as described in BLOCK 12?

- Has supplemental text been reviewed to identify any conflicts between the text and the system requirements defined in BLOCKS 3-11? Remove any conflicts in the text or reaccomplished analysis to resolve deficiencies.

4.15.11 Perform Traceability Analysis: Block 13

- Have all system requirements (functions, contraints, control and information flows, etc.) been associated with primary and secondary source reference?

- Have all system requirements which have no source references been eliminated?

APPENDIX A - GLOSSARY

This appendix consists of definitions of the major terms used throughout this document and concludes with a list of acronyms and abbreviations. The definitions are drawn from a variety of sources which are identified at the conclusion of the definition section.

DEFINITIONS

Acquisition Life Cycle - The five phases of system and related item acquisition (Conceptual, Validation, Full-Scale Development, Production and Deployment) with three key decision points (Program, Ratification, and Production Decisions) between each of the first four phases. A program may skip a phase, have program elements in any or all other phases, or have multiple decision points per phase. (AFR 800-2) [1] (See also System/Acquisition Life Cycle). These phases are being redefined [12], [13].

And - Activities preceding the AND must be accomplished before the flow may continue.

Authenticate - The act of signifying (by the approval signature of a responsible person of the procuring activity) that the Government is in agreement with the requirements contained in the specification. Authentication by the procuring activity normally will be accomplished on that issue of the specification which is to be the contractual requirement for the baseline which that particular specification defines (MIL-STD-483 (USAF) paragraph 3.4.9). [2]

Availability - The degree to which the system shall be in an operable and committable state at the start of the mission(s) is called for at an unknown (random) point in time [3]. Reliability and Maintainability are interrelated. The formula used to express this relationship is:

$$A = \frac{MTBF}{MTBF \quad MTTR}$$

where

A = Availability
MTBF = Mean Time Between Failure
MTTR = Mean Time to Repair

A figure of merit such as Availability is much more meaningful when applied to systems that operate continuously rather than the use of MTBF. [1] (See also Reliability and Maintainability)

Base Line - A configuration identification document or a set of such documents formally designated and fixed at a specific time during a CI's life cycle. Base lines, plus approved changes from those base lines, constitute the current configuration identification. For configuration management there are three base lines, as follows:

a. Functional Base line. The initial approved functional configuration identification.

b. Allocated Base line. The initial approved allocated configuration identification.

c. Product Base line. The initial approved or conditionally approved product configuration identification. (DOD Directive. 5010.19).[4]

Civil Engineering - This term refers to the Air Force civil engineering functions as they relate to the design, construction maintenance, and operation of facilities necessary to support the acquisition and operation of a system or a major modification program. The impact of the various technical functions on Air Force civil engineering functions must be considered throughout the process of developing and acquiring a supportable and cost-effective system. Civil engineering requirements are derived as a part of the systems engineering process (see AFM 86-1). (See also Engineering Management). [6]

Computer Program - The computer program as it pertains to configuration management is a configuration item defined as a deck of punched cards, magnetic or paper tapes, or other physical medium containing a sequence of instructions and data in a form suitable for insertion into a computer. Computer programs used for administrative purposes and those not associated with system/equipment managed by AFR 65-3 are controlled by AFR 300-2. (See definition under Software). [5]

Computer Program Component (CPC) - A CPC is a functionally or logically distinct part of a computer program configuration item (CPCI) distinguished for purposes of convenience in designing and specifying a complete CPCI as an assembly of subordinate elements. [5], [7]

Computer Program Configuration Item (CPCI) - The computer program as it pertains to configuration management is a configuration item. A CPCI is defined as a deck of punched cards, magnetic or paper tapes, or other physical medium containing a sequence of instructions and data in a form suitable for insertion into a computer. (See also Computer Program) [8]

Computer Program Development Plan (CPDP) - The CPDP is the plan which identifies the actions required to develop and deliver computer program configuration items and necessary support resources. It is prepared by the implementing command or,if the development effort is contracted, the plan may be prepared by the contractor and approved by the implementing command. (AFR 800-14, Vol II) [9]

Computer Program Development Specification - Also called Computer Program Configuration Item Specification, MIL-STD-483 (USAF), see Type B5.

Computer Program Life Cycle - The sequence of activities grouped into phases that characterize the typical process of software production and use. The phases are

Analysis Phase
Design Phase
Coding and Checkout Phase
Test and Integration Phase
Installation Phase
Operation and Support Phase

A particular computer program will undergo these phases at least once during the system acquisition life cycle, however, this may occur entirely in one phase of the system acquisition life cycle (e.g., a mission simulation computer program in the conceptual phase) or over several system acquisition phases (e.g., a mission application program developed over the validation, full-scale development and production phases). See AFR 800-14 Volume II, Section 2-8, for further discussion of the computer program life cycle in the system acquisition life cycle. [8]

Concept of Operations. A verbal or written statement, in broad outline, of a commander's assumptions or intent in regard to an operation or series of operations. The concept of operations frequently is embodied in campaign plans and operation plans, in the latter case particularly when the plan covers a series of connected operations to be carried out simultaneously or in succession. The concept is designed to give the overall picture of the operation. It is included primarily for additional clarity of purpose and is frequently referred to as commander's concept. (Source: JCS Pub. 1) [13].

Conceptual Phase - The initial period when the technical, military, and economic bases for acquisition programs are established through comprehensive studies and experimental hardware development and evaluation. The outputs are alternative concepts and their characteristics (estimated operational, schedule, procurement, costs, and support parameters) which serve as inputs to the Decision Coordinating Paper (DCP) on major systems, Program Memoranda (PM) on smaller systems/equipment, and to HQ USAF decision documents (Program Management Directives) for programs that do not require OSD decisions. (AFR 800-2) [1] (see also Acquisition Life Cycle

Configuration - The functional and/or physical characteristics of hardware/software as set forth in technical documentation and achieved in a product. (DOD Directive 5010.19) [4]

Configuration Control - The systematic evaluation, coordination, approval or disapproval, and implementation of all approved changes in the configuration of a CI after formal establishment of its configuration identification. (DOD Directive 5010.19) [4]

Configuration Item (CI) - An aggregation of hardware/computer programs of any of its discrete portions, which satisfies an end-use function and is designated by the Government for configuration management. CIs may vary widely in complexity, size and type, from an aircraft, electronic or ship system to a test meter or round of ammunition. During development and manufacture of the initial (prototype) production configuration, CIs are those specification items whose functions and performance parameters must be defined (specified) and controlled to achieve the overall end-use function and performance. Any item required for logistic support and designated for separate procurement is a configuration item. (AFR 65-3) [1] The third level in the functional hierarchical structure. (See also System Segment, Functional Area, and CPCI)

Configuration Management - A discipline applying technical and administrative direction and surveillance to (1) identify and document the functional and physical characteristics of a configuration item, (2) control changes to those characteristics, and (3) record and report change processing and implementation status. (DOD Directive 5010.19, AFR 65-3, AFR 800-3) [4],[6] (See also Engineering Management)

Constraints - Performance Requirements, Physical Requirements, Operability, Test Requirements, and Design Requirements.

Contractor - An individual, partnership, company, corporation, or association having a contract with the procuring activity for the design, development, design and manufacture, maintenance, modification or supply of items under the terms of a contract. A government activity performing any or all of the above actions is considered to be a contractor for configuration management purposes. [4]

Control Flow (also called Functional Flow) - The description of the logical flow in which the system functions are accomplished in order to control the system functions and satisfy the operational requirements. The control flow indicates only the relationship between system functions and does not imply any lapse in time or intermediate activity. Conditions which determine the flow directions are described using the control-flow relationships: SERIES, AND, OR, and UTILIZES.

Decision Coordinating Paper (DCP) - The principle document to record essential system program information for use in support of the Secretary of Defense/Secretary of the Air Force decision making process. A DCP intended for final approval by the Secretary of the Air Force is called an Air Force Decision Coordinating Paper (AFDCP). (Ref: AFR800-2) [13]

Deficiency - Operational need minus existing and planned capability. The degree of inability to successfully accomplish one or more mission tasks or functions required to achieve mission or mission area objectives. Deficiencies might arise from changing mission objectives, opposing threat systems, changes in the environment, obsolesence, or depreciation in current military assets. [13]

Dependability - Dependability addresses the issues of system survivability, vulnerability (S/V) and external electromagnetic interference. Survivability is the ability of the system to achieve its mission under the conditions of a man-made hostile environment. In addition the system may be required to operate under the conditions of interference from external electromagnetic sources (Electromagnetic compatibility) as well as operate under threat of possible electronic countermeasures (ECM) such as spoofing and jamming.

Deployment Phase - The period beginning with the user's acceptance of the first operational unit and extending until the system is phased out of the inventory. It overlaps the production phase. (AFR 800-2) [1]

DERIVES - This relationship indicates that a function on the path derives either external information (external output) or internal system information (internal output) as part of its activities. (See also Information Flow)

Design and Construction - Minimum or essential requirements that are not controlled by performance characteristics, interface requirements, or referenced documents shall be specified. They shall include appropriate design standards, requirements governing the use or selection of materials, parts and processes, interchangeability requirements, safety requirements, and the like. Requirements for materials to be used in the item or service covered by the specification shall be stated, except where it is more practicable to include the information in other paragraphs. Requirements of a general nature should be first, followed by specific requirements for the material. Definitive documents shall be referenced for the material when such documents cover materials of the required quality. [3]

Design Engineering - This function uses the technical information (requirements, goals, criteria, constraints, etc.) developed through the systems engineering process to develop detailed design approaches, design solutions, and the test procedures to prove these solutions. [6] (See also Engineering Management)

Design Requirements - The minimum or essential design and construction requirements which are not addressed by other constraint requirement types: performance, physical, operability, and test requirements. During the initial phases of systems requirements engineering, certain design and construction standards (see Design and Construction) may be specified directly or by reference to other specifications or standards. As the system development continues, engineering analysis and trade study results (as well as other engineering activities such as prototyping and simulations) may indicate the need for additional design constraints which are practicable and necessary for the system's operation and maintenance (O&M).

Development (Part I or Type B5) Specification - A document which specifies the requirements peculiar to the design, development, functional performance, test, and qualification of the configuration item. It establishes performance criteria and test criteria for which the program shall be designed/ developed [MIL-STD-483(USAF)]. [7] (See also Type B Specification and Specifications)

Development Test & Evaluation (DT&E) - That testing and evaluation of individual components, subsystems, and, in certain cases, the complete system, which is conducted predominantly by the contractor. [7]

Discrete Event Simulation - On the system level, a discrete event simulation may be utilized to support computer system studies. A discrete event simulation is one in which information blocks and computer program timing can be replicated allowing evaluation of throughput capability and identification of potential design problems. This type of simulation is used to check the software design for possible discrepancies that might cause the system to be saturated as a result of either information overloads or time responses that are slower than required. These studies provide estimates of computer sizing and timing for the processing requirements and they evaluate the real-time computational conflicts, including the effects of interrupts. [9] (see also functional simulation, Scientific Simulation, Engineering Simulation)

Electromagnetic Compatibility (EMC) - Defined as "the capability of an equipment, component, subsystem or system to operate in its operational electromagnetic environment at design levels of efficiency, without causing or suffering unacceptable degradation due to electromagnetic interference." The application of approved EMC standards in the development and procurement of equipment is required by AFR 80-23 (para 6d). [1] Where applicable, requirements pertaining to electromagnetic radiation shall be stated in terms of the environment which the item must accept and the environment which it generates. [3]

Electronic Warfare (EW) - The mission capability of Command, Control & Communications systems is continually threatened by the possibility of electronic countermeasures (ECM) such as spoofing and jamming. Potential adversaries put a high emphasis on ECM and have a constantly improving ECM technology base. To be responsive, each Command, Control & Communications system concept must have as little potential for ECM exploitation as possible, electronic counter-counter measure (ECCM) technology base must be vigorous, and incorporation of ECCM into systems must be timely. [1]

Engineering Change - An alteration in the configuration item or items, delivered, to be delivered, or under development, after formal establishment of its configuration identification. [4]

Engineering Change Proposal (ECP) - A term which includes both a proposed engineering change and the documentation by which the change is described and suggested. [4]

Engineering Management - The management of the engineering and technical effort required to transform a military requirement into an operational system. It includes the system engineering required to define the system performance parameters and prefered system configuration to satisfy the requirement, the planning and control of technical program tasks, integration of the engineering specialties, and the management of a totally integrated effort of design engineering, specialty engineering, test engineering, logistics engineering, and production engineering to meet cost, technical performance and schedule objectives. The engineering management task of the government program office assures that the technical functions in the program office are properly planned and implemented, and that the technical functions performed under contract are tailored, monitored, and controlled to best meet the needs of the system or program. These functions (together with certain supporting functions) are: Systems Engineering (including Requirements Engineering), Design Engineering, Specialty Engineering, Test Engineering, Production Engineering, Logistics Engineering, Civil Engineering, Human Factors Engineering, Configuration Management, Technical Data Control, and Technical Program Planning and Control. [10]

Engineering Simulation - Engineering simulation is a further refinement of the scientific simulation in which the final software design is evaluated by driving this software with realistic input data generated from representative scenarios. These simulations, executed on a general purpose computer, are characteristic of the types of tools needed in system and software requirements definition and evaluation. [9] (See also functional simulation, discrete event simulation, scientific simulation)

Environmental Conditions - Environments that the system or equipment is expected to experience in shipment, storage, service, and use. The following subjects should be considered for coverage: natural environment (wind, rain, temperature, etc.); induced environment (motion, shock, noise, etc.); electromagnetic signal environment; shipboard magnetic environment; and environmental conditions due to enemy action (over-pressure, blast, underwater explosions, radiation, etc.).

External Interface - (Also called Intra-System Interface). The interfaces between the system being specified and other systems with which it must be compatible. [3] (See also Interface)

Formal Qualification Tests (FQT) - A formal test conducted in accordance with the Air Force-approved test plans and designed to be a complete and comprehensive test of the CPCI prior to FCA. It is conducted after the design process culminates (AFR 80-14, Vol. II). [7]

Full-Scale Development Phase (FSD) - The period when the system/equipment and the principal items necessary for its support are designed, fabricated, tested, and evaluated. The intended output is, as a minimum, a preproduction system which closely approximates the final product, the documentation necessary to enter the production phase, and the test results which demonstrate that the production product will meet stated requirements. (AFR 800-2) [1] (see also Acquisition Life Cycle)

Function (Functional Requirement Set, Functional Requirements) - A function is a discrete activity within a system. The functional requirements represent the total discrete system activities required to achieve a specific objective, this is most often referred to as the mission objective. A functional requirement identifies what must be accomplished without identifying any aspect concerning the means such as hardware, computer programs, personnel, facilities, or procedural data. Functional requirements represent a problem statement devoid of any overtones or specifics regarding real or conceptual solutions which satisfy any or part of the needed functions.

Note 1: Functions take on different meanings within the three types of system documentation as required by MIL-STD-483 (USAF). Type A specification functions are defined for the system as a whole as defined above. Type B5 specifications define CPCI function to include the inputs, processing, and outputs. The Computer Program Components (CPCs) of the Type C5 specification may correspond to the functions in the Type B5 specification, if the B5 requirements satisfy the computer program developer's design approach. (See [11], para. 4.3.1 and Appendix A4)

For the purpose of requirements engineering, functions are defined to be the same as Type A Specification functions. In documenting functions in Type B5 specifications, the associated inputs and outputs are included.

Note 2: The revised AFR 57-1 provides a slightly different definition of a function: The action for which a system or equipment item is specially fitted or used. [13]

<u>Functional Analysis</u> - System functions and sub-functions shall be progressively identified and analyzed as the basis for identifying alternatives for meeting system requirements. System functions as used above include the mission, test, production, deployment, and support functions. All contractually specified modes of operational usage and support shall be considered in the analysis. System functions and sub-functions shall be developed in an iterative process based on the results of the mission analysis, the derived system performance requirements, and the synthesis of lower-level system elements. Performance requirements shall be established for each function and sub-function identified. When time is critical to a performance requirement, a time line analysis shall be made. [10] (See also Systems Engineering)

<u>Functional Area</u> - A distinct group of system performance requirements which, together with all other such groupings, forms the next lower level breakdown of the system on the basis of function. [4] The second level in the functional hierarchical structure. (See also System Segment, CI and CPCI)

<u>Functional Characteristics</u> - Quantitative performance, operating and logistic parameters and their respective tolerances. Functional characteristics include all performance parameters, such as range, speed, lethality, reliability, maintainability, and safety. (DOD Directive 5010.19) [4]

<u>Functional Hierarchical Structure</u> - This form of organization is suited for structuring system functional requirements in a logical arrangement of subordinate discrete activities which must be performed. The functions of the system are grouped into higher levels of organization representing the

first possible breakout of the system. Upper-level functions are refined by the identification of subordinate levels. Each level of the hierarchy is limited to six functions or less. (See also System Segment, Functional Area, Configuration Item, Computer Program Configuration Item)

Functional Performance - The ability of the software to satisfy its mission requirements as allocated from the System Specification and as contractually specified in the Development Specification. [2]

Functional Requirements - see Function

Functional Simulation - A functional simulation generally consists of a set of building blocks which functionally define the basic elements of the system such as the sensor models, aircraft dynamics, navigation, weapon delivery, and the environment. This type of simulation is used to analyze performance in support of system requirements definition. To support this analysis activity, the simulation may be utilized to generate mission scenarios in order to evaluate system performance parameters and tradeoff studies associated with various system elements, such as the sensors, etc. [9] (See also discrete event simulation, scientific simulation, engineering simulation)

Government Furnished Property (GFP) - Contracts may require the use of GFP, either as end item design requirement or as a part of the system. In such cases, a schedule is included in the contract for delivery of the GFP to the contractor at a date permitting his evaluation for serviceability before it is needed for installation. Engineering data on the GFP must be provided at a date which permits the contractor's engineers to incorporate it, or the interface with it, into the design of the system. [1]

Human Engineering - Human Engineering is usually a contractor design and review process that interacts with other processes such as mission requirements analysis, functional analysis and requirement allocation, the development of workspace mockups, equipment detail design, test and evaluation, etc. (MIL-H-46855A applies.) The contractor is tasked to identify and investigate areas where interactions of human performance and other elements of the system are critical to the system-effectiveness. The contractor's end task is to translate controller/situation, human/information and man/machine functional interface requirements into human engineering design criteria for incorporation into system, equipment, software and facility specifications and delivered products. [1] (See also Human Factors Engineering)

Human engineering requirements for the system/item should be described in specifications and applicable documents (e.g., MIL-STD-1472) included by reference. The specifications should also specify any special or unique requirements, e.g., constraints on allocation of functions to personnel, and communications and personnel/equipment interactions. Included, should be those specified areas, stations, or equipment that require concentrated human engineering attention due to the sensitivity of the operation or criticality of the task, i.e, those areas where the effects of human error would be particularly serious. [3]

Interfaces between software and the user should be specified in the Development (Part I) Specification. Inputs and outputs should be self explanatory, easy to learn and understand, unambiguous, and designed to avoid misinterpretation. [2]

Human Factors Engineering - This function is a part of the mainstream engineering effort throughout the system life cycle. It uses data from, and contributes to, the system engineering process in developing a best mix of specification requirements. Its objective is to ensure that the human component of the system can safely and effectively operate, maintain, support, and control the system in its intended operational environment. It is also concerned with providing engineering data for use in hardware, software, or people cost-effective trade studies, and with developing plans for training and training equipment (see AFR 800-15). [6] (See also Engineering Management and Human Engineering)

Implementing Command - The command or agency designated by Program Management Directive (PMD) as responsible to achieve the program objectives or program phase objectives established in the PMD. (Ref: AFR 800-2) [13]

The Air Force command responsible for the acquisition of the system (subsystem or item). The procuring activity is usually resident within the Implementing Command. Program management responsibility normally is transferred to the designated supporting command according to a predetermined agreement. Similarly, the responsibility of system operation and maintenance is turned over to the using command. [8]

Information Flow - The description of the flow of information into, within, and out of the system. The information flow builds upon the I/O hierarchical structure by providing a means of analyzing the system as an information processing system. During this analysis, the flow relationships between external system inputs and resulting outputs are identified. This method permits the various relationships between associated functions and the internal information necessary to support the derivation of the output to be identified. The flow associations between system information are described using the information-flow relationships: USES, DERIVES, UPDATES, PROVIDES, and RECEIVES. The informational flow indicates only the relationship between system functions, system information (external and internal system I/O), and using activities (organizations, operational units, or positions) and does not imply any lapse in time or intermediate I/O being used, derived, or updated.

Initial Operational Capability (IOC). The first attainment of the capability to employ effectively a weapon, item of equipment, or system of approved specific characteristics, and which is manned or operated by an adequately trained, equipped, and supported military unit or force. (Source: JCS Pub. 1) [13]

I/O Hierarchical Structure - The logical hierarchical description of the discrete system inputs and outputs (external I/O) and the internal information requirements necessary for the system's operation. The emphasis on the I/O structure is to arrange the information requirements into structures by breaking the information into logical subordinate parts or simply as groupings of information. The well-organized structure is effective in communicating the I/O requirements and for identifying missing I/O requirements.

Interface - The functional and physical characteristics required to exist at a common boundary between two or more equipments/computer programs. Interfaces between equipment/computer programs provided by different developing agencies (contractors), or between development items and government furnished property or external systems, require explicit documentation. [8] (See also External Interface and Internal Interface)

Life Cycle Cost (LCC). The total cost of an item or system over its full life. It includes the cost of acquisition, ownership (operation, maintenance, support, etc.) and, where applicable, disposal. To be meaningful, an expression of life cycle cost must be placed in context with the cost elements included, period of time covered, assumptions and conditions applied, and whether it is intended as a relative comparison or absolute expression of expected cost effects. (Source: AFR 800-11) [13]

Internal Interface (also called Inter-System Interface) - The interfaces between and within the system being specified (e.g., between system segments, functional areas, configuration items) [3] (See also Interface)

Life Cycle Cost Analysis - Life Cycle Cost Analysis is performed by the contractor periodically throughout the acquisition to access the cost of acquisition and ownership. This effort results in an identification of the economic consequences of system design alternatives. [10] (See also Systems Engineering)

Logical Organizational Relationships - Logical organizational relationships are shown by structuring the discrete functions and the information requirements (external and internal input/output) of the system into hierarchical structures: Functional Hierarchical Structure, and I/O Hierarchical Structure.

Logistics Engineering - This function provides inputs to the systems engineering process in all acquisition phases. In general, these inputs are the support environment descriptors and constraints. This function uses the technical data developed by the systems engineering process to refine the support plans, concepts, and requirements for system support in the deployment phase and in operational utilization. The logistics engineering function is a part of the mainstream engineering effort to develop and achieve a supportable and cost-effective system. This function uses the detailed drawings which are prepared by design engineering to develop the specific support requirements; that is, to develop such specific support items as tools, test equipment, personnel skills, and maintenance procedures. (For other information concerning logistics engineering responsibilities, see AFR 800-8 and AFP 800-7.) [6] (See also Engineering Management)

Logistics Support Analyses - The contractor is usually tasked to conduct logistic support analyses leading to the definition of support needs (e.g., maintenance equipment, personnel, spares, repair parts, technical orders, manuals, transportation and handling, etc.). These analyses address all levels of operations and maintenance and results in requirements for support. [10] (See also Systems Engineering)

Maintainability - Closely related and inseparable from Reliability is the specialty, Maintainability. Maintainability is a characteristic of the design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time when the maintenance is performed using prescribed procedures and resources. (See also Reliability and Availability) [1] The revised AFR 57-1 emphasizes the following definition: a measure of the time or maintenance resources needed to keep an item operating or restore it to operational (or in the case of certain munitions, serviceable) status. Maintainability may be expressed as the time to do maintenance, as the total required manpower, or as the time to restore a system to operational (or serviceable) status. (Source: AFR 80-5) [13]

Numerical maintainability requirements shall be stated in such terms as mean-time-to-repair (MTTR) or maintenance man-hours per flight/operational hour. Determination of realistic requirements is necessary. Qualitative requirements for accessibility, modular construction, test points, and other design requirements may be specified as required. [3]

Specifications shall specify the quantitative maintainability requirements. The requirements shall apply to maintenance in the planned maintenance and support environment and shall be stated in quantitative terms. Examples are:

a. Time (e.g., mean and maximum downtime, reaction time, turnaround time, mean and maximum times to repair, mean time between maintenance actions).

b. Rate (e.g., maintenance manhours per flying hour, maintenance manhours per specific maintenance action, operational ready rate, maintenance hours per operating hour, frequency of preventive maintenance).

c. Maintenance complexity (e.g., number of people and skill levels, variety of support equipment).

d. Maintenance action indices (e.g., maintenance costs per operating hour, manhours per overhaul). [3]

Maintainability as applied to software is specification, design, and development of code in a manner which facilitates the task of modification to correct deficiencies and to satisfy new or changing requirements. A potential source of confusion exists regarding subtle distinctions between the hardware and software definition of maintainability. Hardware maintenance is the restoration of hardware to its original design, whereas software maintenance is defined as both error correction and modification of the original design (both of which imply change rather than restoration)

Since there is little chance that the usage of either set of definitions will be discontinued, the procuring agency should bear these differences in mind when participating in the establishment of maintainability criteria for the total system. Software maintenance features in terms of growth requirements may be specified in the Development (Part I) Specification. Additional features such as modularity should be requested in the RFP, responded to in the CPDP, and implemented by the contractor in the design, and reflected in the Product (Part II) Specification. [2]

Maintenance Concept. A description of maintenance considerations and constraints. A preliminary maintenance concept is developed and submitted as part of the preliminary operational concept for each alternative solution candidate by the operating command with the assistance of the implementing and supporting commands. The preliminary maintenance concept is refined during the demonstration and validation phase to become the system maintenance concept during full scale engineering development (FSED). During FSED, the system maintenance concept is expanded in scope and detail and removed from the system operational concept to become the maintenance plan. (Source: AFR 66-14) [13]

Milestone Zero Decision. The program initiation decision by competent authority that valid mission need exists and alternative solutions should be systematically and progressively identified and explored. Secretary of Defense approval of the need is required to initiate major system acquistion programs. Secretary of the Air Force approval is required to initiate Air Force designated acquisition programs (AFDAP). HQ USAF approval by PMD is required to initiate all other acquisition programs. [13]

Mission Area. A segment of the defense mission as established by the Secretary of Defense. (Source: AFR 800-2) [13]

Mission Area Analyses. Continuous analysis of assigned mission responsibilities in the several mission areas to identify deficiencies in the current and projected capabilities to meet essential mission needs and to identify opportunities for the enhancement of capability through more effective systems and less costly methods. Missions area analysis should conform with short, mid, and long range planning guidance. The objectives of mission area analysis are to identify capability deficiencies and assess the relative values of operational needs. [13]

Mission Area Planning. A continuous HQ USAF and command planning activity which directs and coordinates mission area analysis and uses the product of that analysis to help make program, budget, modification and acquisition, force structure, strategy and tactics decisions. [13]

Mission Element. A segment of a mission area critical to the accomplishment of the mission area objectives and corresponding to a recommendation for a major system or designated non-major system capability as determined by the Air Force. (Ref: AFR 800-2) [13]

Mission Element Need Analysis (MENA). A mandatory attachment of the SON which cites the command mission and tasks, documents of the salient results of the mission analysis which identified the operational deficiency, states command needs for mission task performance, and provides constraints on acceptable solutions. [13]

Mission Element Need Statement (MENS). A statement prepared by HQ USAF to identify and support the need for a new or improved mission capability. It is normally based on one or more SONs. The mission need may result from a projected deficiency or obsolescence in existing systems, a technological opportunity, or an opportunity to reduce operating cost. The MENS is submitted to the SECDEF or SAF as appropriate for a Milestone 0 decision. (Ref: DOD Directive 5000.2) [13]

Mission Reliability. A measure of the ability of a system to complete its planned mission or function. Mission reliability may be expressed as Mission Completion Success Probability (MCSP), Mean Mission Duration (MMD), or as Mean Time Between Critical Failure (MTBCF) as appropriate. (Source: AFR 80-5) [13]

Mission Requirements Analysis - Impacts of the stated system operational characteristics, mission objectives, threat, environmental factors, minimum acceptable system functional requirements, technical performance, and system figure(s) of merit as stipulated, proposed, or directed for change are analysed during the conduct of the contract. These impacts are examined continually for validity, consistency, desirability, and attainability with respect to current technology, physical resources, human performance capabilities, life cycle costs, or other limitations. The output of this analysis will either verify the existing requirements or develop new requirements which are more appropriate for the mission. [10] (See also Systems Engineering and System Capability requirements)

Operability. (Sometimes called System-Effectiveness or System Operational Effectiveness) - Operability includes system availability and dependability. Availability incorporates the aspects of reliability and maintainability; dependability incorporates the aspects of survivability and vulnerability (S/V). Each of these operability categories may be influenced by design related issues, policy related impact, or non-controllable factors.

Operating Command. The command or agency primarily responsible for the operational employment of a system, subsystem or item of equipment. The operating command usually submits the SON. The operating command is a participating command. (Ref: AFM 11-1, Vol I) [13]

Operational Concept. A statement about intended employment of forces that provides guidance for posturing and supporting combat forces. Standards are specified for deployment, organization, basing, and support from which detailed resource requirements and implementing programs can be derived. (Source: (AFM 11-1, Vol I) [13] influencing the system/equipment design. On the other hand, the manpower agency may request program office support in determining the appropriate manning for a new or complex system. In this case the program office can task the contractor to perform studies for determining the manpower requirements. [1]

Physical Characteristics - Quantitative and qualitative expressions of material features, such as composition, dimensions, finishes, form, fit, and their respective tolerances (DOD Directive 5010.19). [4] These characteristics in a development, product or material specification shall set forth requirements such as weight limits, dimensional limits, etc., necessary to assure physical compatibility with other elements and not determined by other design and construction features or referenced drawings. They shall also include considerations such as transportation and storage requirements, security criteria, durability factors, health and safety criteria, command control requirements, and vulnerability factors. [3] (See also Physical Requirements)

Physical Requirements - Physical requirements are those requirements which constrain or significantly influence the design solution in a physical manner. The physical constraints include power, physical features (size and weight), environmental considerations (controlled or natural), human performance capabilities and limitations (human factors), predetermined internal system interfaces (inter-system interfaces) and external system interfacing (intra-system interfaces), use of existing equipment (off-the shelf) and Government Furnished Property (GFP), and use of standard parts. (See also Physical Characteristics)

Preliminary Qualification Tests (PQT) - A formal test conducted in accordance with Air Force-approved test plans and designed to be an incremental process which provides visibility and control of the computer program development during the time period between CDR and FQT. A PQT should be conducted for those functions which are critical to the CPCI (AFR 800-14, Vol. II). [7]

Procuring Activity (Also called Procuring Agency) - The collection of administrative, management and technical expertise which is organized under a program manager directly responsible for the acquisition of a system. The term System Program Office (SPO) is used in the Electronic Systems Division (ESD) of AFSC to designate a procuring activity responsible for a large system acquisition. [8] (See also Program Office and Implementing Command)

Production Engineering - This function uses the technical data developed through the systems engineering process to develop the plans and procedures for tooling, materials, quality assurance, and manufacturing. The production engineering function is a part of the mainstream engineering effort to develop and achieve producible and cost-effective design solutions. (For other information concerning production engineering responsibilities, see AFR 800-9) [6] (See also Engineering Management)

Production Engineering Analysis - Production engineering analysis is an integral part of the system engineering process. It includes producibility analyses, production engineering inputs to system effectiveness, trade-off studies, and life cycle cost analyses and the consideration of the materials, tools, test equipment, facilities, personnel, and procedures which support manufacturing in RDT&E and production. Critical or special producibility requirements are identified as early as possible and are an input to the program risk analysis. Where critical or special production engineering requirements limit the design, these requirements are included in applicable specifications. Long lead time items, material limitations, transition from development to production, special processes, and manufacturing limitations are considered and documented during the system engineering process. The contractor identifies and takes necessary steps to reduce high-risk manufacturing areas as early as possible. [10] (See also Systems Engineering)

Production Phase - The period from production approval until the last system/ equipment is delivered and accepted. The objective is to efficiently produce and deliver effective and supportable systems to the operating units. It includes the production and deployment of all principal and support equipment. (AFR 800-20 [1])

Product Specification - A document or series of documents which contain the detailed technical description of the CPCI as designed and coded. It is a complete description of all routines, limits, timing, flow, and data base characteristics of the computer program, limits, timing, flow, and data coded instructions. Equivalent to "Part II CPCI specification" or "Type C5 Specification". [7] (See also Type C Specification and Specifications)

Program Management Directive (PMD) - The official HQ USAF management directive used to provide direction to the implementing and participating commands and satisfy documentation requirements. It will be used during the entire acquisition cycle to state requirements and request studies as well as initiate, approve, change, transition, modify or terminate programs. The content of the PMD, including the required HQ USAF review and approval actions, is tailored to the needs of each individual program. (AFR 800-2) [1]

Program Management Plan (PMP) - The document developed and issued by the Program Manager which shows the integrated time-phased tasks and resources required to complete the task specified in the PMD. It defines the support required from all participating organizations, is tailored to the needs of each individual program, and contains only that information deemed necessary by the program manager. (AFR 800-2) [1]

Program Office (PO) - The field office organized by the program manager to assist him in accomplishing the program tasks. (AFR 800-2) (See also Procuring Activity) [1]

PROVIDES - This relationship indicates that a using activity is the source of the external output. (See also Information Flow)

Quality Requirements. The term 'quality requirements' denotes system requirements which are complete, consistent, testable, and traceable. This characteristic is the result of the requirements being discretely identified and well-organized. (see also Requirements Engineering)

RECEIVES - This relationship indicates that a using activity is the recipient of the external output. (See also Information Flow)

Reliability - As defined in AF Regulation 80-5, Reliability and Maintainability Programs for Systems, Sybsystems, Equipment, and Munitions, Reliability is the probability that a part, components, subassembly, assembly, subsystem or system will perform for a specified interval under stated conditions with no malfunction or degradations that require corrective maintenance actions. Hardware reliability may also be expressed in terms such as Mean Time Between Failure (MTBF) or Mean Time Between Maintenance Action. [1]

Reliability requirements shall be stated numerically with confidence levels, as appropriate, in terms of mission success or hardware mean time between failures. Initially, reliability may be stated as a goal and a lower minimum acceptable requirement. During contract definition, or equivalent period, realistic requirements shall be determined and incorporated in the specification with requirements for demonstration. Reliability requirements shall never be stated as a goal in Type C (product) specifications. [3]

Reliability is a difficult and perhaps inappropriate term when applied to software because this item has an entirely different meaning for hardware. Since a computer program never wears out it is virtually impossible to predict or analyze failure rates. Any failure of the computer program is a latent design deficiency and its occurrence cannot be adequately predicted. In this respect a computer program cannot be designed for reliability and cannot be tested or evaluated for reliability. Reliability should not apply to computer programs as end items although the computer programs may be used to enhance system reliability. [2] (See also Availability and Maintainability)

Required Operational Capability (ROC) - The ROC identifies the need for a new or improved operational capability. The formal numbered document used under previous editions of AFR 57-1, (27 Nov 1963 through 31 Aug 1977) to identify an operational need and to request a new or improved capability for the operating forces. [13] Once the ROC is validated by HQs USAF, the PMD, which authorizes AFSC to establish a Program Office cadre, is issued. [2]

Requirements Allocation - Each function and sub-function shall be allocated a set of constraint requirements. These requirements shall be derived concurrently with the development of functions, time-line analyses, synthesis of system design, and evaluation performed through trade-off studies and system/ cost effectiveness analysis. Time requirements which are prerequisites for a function or set of functions affecting mission success, safety, and availability shall be derived. The derived requirements shall be stated in sufficient detail for allocation to hardware, computer programs, procedural data, facilities, and personnel. When necessary, special skills or peculiar requirements will be identified. Allocated requirements shall be traceable through the analysis by which they were derived to the system requirement they are designed to fulfill. [10] (See also Systems Engineering)

Requirements Analysis - (See Requirements Engineering)

Requirements Definition - (See Requirements Engineering)

Requirements Engineering - An iterative process of defining the system requirements and analyzing the integrity of the requirements. This process involves all areas of system development preceding the actual design of the system. The products of the requirements engineering process can be evaluated for completeness, consistency, testability, and traceability. The essential goal of requirements engineering is to thoroughly evaluate the needs which the system must satisfy. (See also Engineering Management)

Requirement Types - See System Requirements

Requirements Traceability - See Traceability

Safety - Requirements for system safety are described to preclude or limit hazard to personnel, equipment, or both. To the extent practicable, these requirements are imposed by citing established and recognized standards. Limiting safety characteristics peculiar to the item due to hazards in assembly, disassembly, test, transport, storage, operation or maintenance are stated when covered neither by standard industrial or service practices nor the system specification. "Fail-safe" and emergency operating restrictions are included when applicable. These include interlocks and emergency and standby circuits required either to prevent injury or provide for recovery of the item in the event of failure. [3] (See also System Safety)

Scientific Simulation - Scientific simulation is the primary simulation used in detailed computer program requirements definition and algorithm design. Scientific simulation consists of a functional simulation (for example, FORTRAN version) of the proposed end-item software, interfaced with simulations representing sensor and environmental models. Such a scientific simulation allows the study of the major end-item software, and provides further information to be used for system performance evaluation. [9] (See functional simulation, discrete event simulation, engineering simulation)

Segment - (See System Segment)

Simulation - See Functional Simulation, Discrete Event Simulation, Scientific Simulation, Engineering Simulation.

Software - Software denotes computer programs and computer data. A computer program is a series of instructions or statements in a form acceptable to a computer, designed to cause the computer to execute an operation or operations. Computer programs include operating systems, assemblers, compilers, interpreters, data maintenance/diagnostic programs, as well as applications programs such as payroll, inventory control, operational flight, strategic, tactical automatic test, crew simulator, and engineering analysis. Computer programs may be either machine-dependent or machine-independent, and may be general-purpose in nature or be designed to satisfy the requirements of a specialized process or particular users. Computer data is a collection of data in a form capable of being processed and operated on by a computer, such as a data base, or analog or digital inputs to a computer program that are necessary for its operation. [2], [8] (See also Computer Program)

Speciality Engineering - This term refers to the engineering efforts of reliability, maintainability, safety, survivability, vulnerability, corrosion prevention, structural integrity, etc. These engineering functions are part of the mainstream engineering effort to develop a best mix of specification requirements and achieve cost-effective design solutions. [6] (See also Engineering Management)

Specification (See also Systems Engineering) - A document intended primarily for use in procurement, which clearly and accurately describes the essential technical requirements for items, materials or services including the procedures by which it will be determined that the requirements have been met. (DOD Directive 4120.3) [4] MIL-STD-490 and MIL-STD-483 Specification types are:

System specification. A document which states the technical and mission requirements for a system as an entity, allocates requirements to functional areas (or configuration items), and defines the interfaces between or among the functional areas. (See also Type A) [4]

Development specification. A document applicable to an item below the system level which states performance, interface, and other technical requirements in sufficient detail to permit design, engineering for Service use, and evaluation. (see also Type B) [4]

Product specification. A document applicable to a production item below the system level which states item characteristics in a manner suitable for procurement, production and acceptance. (See also Type C) [4]

Statement of Operational Need (SON). A formal numbered document used to identify an operational deficiency and state the need for a new or improved capability for USAF forces. Operational needs are based on short term and long term capability objectives and may result from a projected deficiency or obsolescence in existing capabilities, a technological opportunity, or an opportunity to reduce operating/support cost. It usually begins the system acquisition process and is normally followed by the conceptual phase, however, any appropriate phase may follow. Satisfying a SON will normally require a combination of research, development, test, modification, or acquisition efforts that will enhance USAF forces' capabilities. [13]

Supporting Command - A command providing direct support to a system or test program. Examples include the Air Force Logistics Command (AFLC) and the Air Training Command (ATC). See also implementing command and using command. [8] The revised AFR 57-1 provides the following definition: The command assigned responsibility for providing logistics support; it assumes program management responsibilty from the implementing command. The supporting command is a participating command. (Ref: AFR 800-2) [13]

Synthesis - Sufficient preliminary design is accomplished to confirm and assure completeness of the performance and design requirements allocated for detail design. The performance, configuration, and arrangement of a chosen system and its elements and the technique for their test, support, and operation are portrayed in a suitable form such as a set of schematic diagrams, physical and mathematical models, computer simulations, layouts, detailed drawings, and similar engineering graphics. These portrayals shall illustrate intra- and inter-system and item interfaces, permit traceability between the elements at various levels of system detail, and provide means for complete and comprehensive change control. This portrayal is the basic source of data for developing, updating, and completing (a) the system, configuration item, and critical item specifications, (b) interfacing control documentation; (c) consolidated facility requirements; (d) content of procedural handbooks, placards, and similar forms of instructional data; (e) task loading of personnel; (f) operational computer programs; (g) specification trees; and (h) dependent elements of work breakdown structures. [10] (See) also Systems Engineering)

System - A composite of items, assemblies (or sets), skills, and techniques capable of performing and/or supporting an operational (or non-operational) role. A complete system includes related facilities, items, material, services, and personnel required for its operation to the degree that it can be considered a self-sufficient item in its intended operational (or non-operational) and/or support environment. (AFR 65-3) [1],[8],[4]

System Acquisition Process. A sequence of specified decision events and phases of activity directed to achievement of established program objectives in the acquisition of Defense systems and extending from approval of a mission need through successful deployment of the Defense system or termination of the program. (Source: AFR 800-2) [13]

System/Acquisition Life Cycle - Normally, it consists of five phases (Conceptual, Validation, Full-Scale Development, Production, and Deployment) with key decision points between each of the first three phases (Program, Ratification, and Production Decisions). A program may skip a phase or have program elements in any or all other phases. (See AFR 800-2 and AFSCP 800-3) (See also Acquisition Life Cycle) [1]

System Capability Requirements - The mission oriented needs which the system must perform to satisfy the requirements of the using agency. (See also Mission Requirements Analysis)

System/Cost Effectiveness Analysis - A continuing system/cost effectiveness analysis insures that engineering decisions, resulting from the review of alternatives, are made only after considering their impact on system effectiveness and cost of acquisition and ownership. The contractor is tasked to identify alternatives which would provide significantly different system effectiveness or costs than those based upon contract requirements. [10]

System Design Concept. An idea expressed in terms of general performance, capabilities, and characteristics of hardware and software oriented either to operate or to be operated as an integral whole in meeting a mission need. (Source: OMB Circular A-109) [13]

Systems Engineering - The application of scientific and engineering efforts to transform an operational need or statement of deficiency into a description of system requirements and a preferred system configuration that has been optimized from a life cycle cost viewpoint. The process of systems engineering has three principal elements: functional analysis, synthesis; and trade studies or cost-effectivess optimization. The process uses a sequential and iterative methodology to reach cost-effectivess solutions. The technical information developed in this process is used to plan and integrate the engineering effort for the system as a whole, during the definition, design, test and evalution, production, deployment, support, and modification of a system or equipment item. (AFR 800-3) [1] (See also Engineering Management)

System engineering for the total system or a functional area (system element or segment) is normally vested in a single contractor or Government agency. System engineering as it relates to configuration management, is the application of scientific and engineering efforts to transform an operational need into a description of system performance parameters and a system configuration must be ultimately called out in the CI specifications. In this way, the system engineering agency or contractor generates requirements for configurations which will satisfy the operational need, constrained technically only by the content of the system specification. The system engineering agency or contractor is responsible for assessing the impact of changes to CI specifications or to the system specification. This includes modifications to operational systems. (See MIL-STD-490 for system engineering criteria.) [1]

The following typical tasks are conducted (as appropriate) in performing system engineering (see separate definitions for each):

Mission Requirements Analysis
Functional Analysis
Requirements Allocation
Synthesis
Logistics Support Analysis
Life Cycle Cost Analysis
Trade-Off Studies
Production Engineering Analysis
Specifications [10]

System Engineering Management Plan (SEMP) - A contractor's proposal describing this approach to system engineering management to be applied in a specific acquisition contract. The SEMP normally consists of three major parts: (1) System Engineering, (2) Technical program planning and control, and (3) Engineering integration. (MIL-STD-499A) [3,5,8]

System Flow Relationships - System flow relationships can be shown be organizing the discrete requirements in terms of control flow and information flow.

System Requirements - System Functions and Constraints

System Safety - Defined by MIL-STD-882 to be the optimum degree of safety within the limits of operational effectiveness, time and cost, attained through specific application of system safety management and engineering principles throughout all phases of a system's life cycle. It is very important to realize that system safety is concerned with the safety of both personnel and equipment. The application of this discipline to ensure the preservation of equipment immediately expands its scope beyond that of the traditional safety field, and establishes it as an engineering area. As implied above, the basic guidance document for system safety is MIL-STD-882, System Safety Program for Systems and Associated Subsystems and Equipment: Requirements for. This is a very broad document and must be tailored to fit the individual program. The other basic document is AFR 127-8, Responsibilities for USAF System Safety Engineering Programs, and the AFSC supplement thereto. This gives specific requirements to be applied to most programs. [1] (See also Safety)

Systems Operational Concept (SOC) - A formal document that describes the intended purpose, employment, deployment, and support of a system. It assists in identifying the variables associated with satisfying the operational need and provides initial guidance to operating forces for employing the new or improved system. It provides information for posturing combat forces and specifies standards for deployment, organization, basing and support from which detailed resource requirements and implementing programs can be derived. It must be compatible with long range Air Force goals and objectives and consistent with Air Force strategy, force structure, concepts for the future employment of aerospace forces, and current and emerging doctrin. Prior to FSED, it contains as an integral part, the maintenance concept prepared per AFR 66-14. [13]

System Segment - A discrete package of system performance requirements, functional interfaces and configuration items allocated to one developing agency directly responsible to the procuring activity for that part of the system's total performance. The term "system segment" can be synonymous with "subsystem" or "functional area"; however, it need not be, and can include part or all of more than one subsystem or functional area if all are the responsibility of the same agency. [8] The first level in the functional hierarchical structure. (See also Functional Area, CI, and CPCI, Type A - System Specification)

System Segment Specification - A specification similar in format to a system specification (Type A format), identifying a discrete package of system performance requirements, functional interfaces, and CIs contracted to one contractor or assigned to one Government organization directly responsible to the procuring activity for that part of a system's total performance. [5] (See System Segment, Type A - System Specification)

System Specification - A document which states all the necessary technical and mission requirements in terms of performance, allocates requirements to functional areas (or configuration items), defines the interfaces between or among the functional areas (or configuration items), and includes the test provisions to assure the achievement of all requirements. [7] (See also Type A - System Specification)

System Training Concept. A document summarizing ATC training policy based on review of user's requirements and planning factors as reflected in the SON and system operational concept and updates. Outlines conceptual guidance on T&E and deployment training planning efforts. It forms the basis for future training planning actions which are documented in the System Training Plan.

Survivability/Vulnerability (S/V) - Survivability is the capability of a system to accomplish its mission despite a man-made hostile environment. The USAF policy is that each system will have enough designed-in hardness and will be operated in a manner so that sufficient numbers will survive the expected threat.

There are direct nuclear and nonnuclear threats to virtually every Command, Control & Communications system, and there is a severe nuclear threat to the atmosphere and ionosphere, the propagation medium for radars and radio communications. Within the nuclear hardening area itself, there are several specialized disciplines. So although it is not difficult to understand the fundamentals of vulnerability and hardening, implementation of a sound survivability program usually requires a number of different specialists.

S/V is important in all phases of a system's life cycle, from concept through operations. Key milestones include the threat study, hardness specification, hardness verification (including testing), and hardness maintenance. The regulations do provide a formal mechanism for establishing survivability criteria, through the Nuclear Criteria Group and the Nonnuclear Survivability Technology Working Group. Mission Hardness design and verification must documented in such a way that AFLC and the operating command can readily maintain system hardness throughout its life, and evaluate the impacts of a changing threat.

Virtually every Command, Control and Communications system must be protected from the effects of electromagnetic pulse (EMP), a broad area nuclear effect. This can be done with sound state-of-the-art electrical engineering. Beyond EMP, hardening becomes very threat specific. [1]

Technical Data Control - This term refers to logging and managing the technical information which is developed by various engineering functions. (For other information concerning technical data control responsibilities, see AFR 310-1.) [6] (See also Engineering Management)

Technical Program Planning and Control - This term refers to the process of planning, monitoring, measuring, evaluating, directing, and replanning the management of the technical program. This process is carried out through such tasks as making risk analyses, developing and updating the work breakdown structure, accomplishing technical performance measurement, conducting technical reviews, performing change studies, and planning and implementing changes. [6] (See also Engineering Management)

Test. Any program or procedure which is designed to obtain, verify, or provide data for the evaluation of: research and development (other than laboratory experiments); progress in accomplishing development objectives; or performance and operational capability of systems, subsystems, components, and equipment items. [13]

Test Engineering - This function uses the technical data developed through the systems engineering process to develop test plans. These plans outline the test procedures and test requirements that are to be used to test the design solutions. (For other information concerning test planning, see AFR 80-14.) [6] (See also Engineering Management)

Test Requirements - The program office initiates the test planning process during the Conceptual Phase by preparing a Test and Evaluation Master Plan (TEMP). During the Validation Phase the contractor(s) initiate detailed test planning relative to hardware and computer program end-items (CIs and CPCIs). These test plans and procedures are submitted to the government for review and approval; the approved plans and procedures are the basis for subsystem and system testing. In order to test system requirements, a unique test must be associated with the appropriate end-item which incorporates requirement(s) to be tested. For those requirements which are inherent in a collection of end-items, the test of a requirement will be realized during system testing. Critical system requirements should be linked to unique end-items and be traceable to the original requirements as described in the MIL-STD-490 Type A and B specifications. Section 4 (MIL-STD-490/483 Type A and B Specifications, Quality Assurance Provisions) identifies the specific requirements for formal test and verification of the system (Type A) and subsequently its end-items (Type B). These test and verification requirements identify what specific system requirements (Section 3 of the specification) must be satisfied. Test requirements, therefore, identify the functional, performance, physical, operability, and design requirements which will be evaluated during system integration and test.

Test & Evaluation Master Plan (TEMP) - The TEMP is an overall plan which identifies and integrates the efforts and schedules of all test and check-out activities to be accomplished in the system development program. [7]

Traceability - (Requirements Traceability, Requirements Traceability Relationships) During the requirements engineering activities, sources of requirements (source documents) are referenced for each requirement identified. These source references provide the means of tracing the requirements from one set of system requirements documentation to the allocated requirements contained in the next level of system documentation, such as from a Type A to Type B specification. Sources for each requirement can also be maintained for pertinent studies, analyses, and plans: PMD, PMP, system sizing and timing studies, prototyping, simulations, test plans and procedures, and the like. The requirements and associated sources provide the means of verifying the requirements during the requirements engineering process and into later phases of the system acquisition by providing a repository of information on the system definition.

Software traceability refers to the capability to follow specific mission requirements through the various levels of specification to the actual code; and the capabilities to associate each area of code with a specified requirement. [2]

Trade-off Studies - Desirable and practical trade-offs among stated operational needs, engineering design, program schedule and budget, producibility, supportability, and life cycle costs, as appropriate, are continually identified and assessed. Trade-off studies are accomplished at the various levels of functional or system detail or as specifically designated to support the decision needs of the system engineering process. Trade-off studies, results and supporting rationale are documented in a form consistent with the impact of the study upon program and technical requirements. [10] (See also Systems Engineering)

Training Equipment - All types of maintenance and operator's training hardware, devices, visual/audio training aids and related software which (a) are used to train maintenance and operator personnel by depicting, simulating or portraying the operational or maintenance characteristics of an item, system or facility, and (b) must, by their nature, be kept consistent in design, construction and configuration with such items in order to provide required training capability.

Transportability - Any special requirements for transportability and materials handling shall be specified. The specifications shall include requirements for transportability which are common to all system equipment to permit employment, deployment, and logistic support. All system elements that, due to operational or functional characteristics, will be unsuitable for normal transportation methods, shall be identified. [3]

Two-part Specifications - Two-part specifications, which combine both development (performance) and product fabrication (detail design) specifications under a single specification number as procuring activity option. This practice requires both parts for a complete definition of both peformance requirements and detailed design requirements governing fabrication. Under this practice, the development specification remains alive during the life of the item as the complete statement of performance requirements. Proposed design changes must be evaluated against both the product fabrication and the development parts of the specification. To emphasize the fact that two parts exist, both parts shall be identified by the same specification number and each part shall be further identified as Part I or Part II, as appropriate. [3]

Type A - System specification (also Segment Specification). This type of specification states the technical and mission requirements for a system as an entity, allocates requirements to functional areas, and defines the interfaces between or among the functional areas. Normally, the initial version of a system specification is based on parameters developed during the concept formulation period or an exploratory preliminary design period of feasibility studies and analyses. This specification (initial version) is used to establish the general nature of the system that is to be further defined during a contract definition, development, or contract design period. The system specification is maintained current during the contract definition, development, or equivalent period, culminating in a revision that forms the future performance base for the development and production of the prime items and subsystems (configuration items), the performance of such items being allocated from the system performance requirements (see MIL-STD-490, Appendix I for outline of form). [3] (See also System Specifications, System Segment Specification)

Type B - Development specifications. Development specifications state the requirements for the design or engineering development of a product during the development period. Each development specification shall be in sufficient detail to describe effectively the performance characteristics that each configuration item is to achieve when a developed item is to evolve into a detail design for production. The development specification should be maintained current during production when it is desired to retain a complete statement of performance requirements. Since the breakdown of a system into its elements involves items of various degrees of complexity which are subject to different engineering disciplines or specification content, it is desirable to classify development specifications by sub-types. [3] (See also Two-part Specifications, Development Specification and Specifications)

Type B5 - Computer program development specification. (See MIL-STD-490, Appendix VI for outline of form.) This type of specification is applicable to the development of computer programs, and shall describe in operational, functional, and mathematical language all of the requirements necessary to design and verify the required computer program in terms of performance criteria. The specification shall provide the logical, detailed descriptions of performance requirements of a computer program and the tests required to assure development of a computer program satisfactory for the intended use. [3] (See also Two-part specifications, Development Specifications, and Specifications)

Type C - Product specifications. Product specifications are applicable to any item below the system level, and may be oriented toward procurement of a product through specification of primarily function (performance) requirements or primarily fabrication (detailed design) requirements.

Sub-types of product specifications to cover equipments of various complexities or requiring different outlines of form are covered in MIL-STD-490, paragraphs 3.1.3.3.1 through 3.1.3.3.5 [3]

A product function specification states (1) the complete performance requirements of the product for the intended use, and (2) necessary interface and interchangeability characteristics. It covers form, fit, and function. Complete performance requirements include all essential functional requirements under service environmental conditions or under conditions simulating the service environment. Quality assurance provisions include one or more of the following inspections: qualification evaluation, preproduction, periodic production, and quality conformance.

A product fabrication specification will normally be prepared when both development and production of the item are procured. In those cases where a development specification (Type B) has been prepared, specific reference to the document containing the performance requirements for the item shall be made in the product fabrication specification. These specifications shall state: (1) a detailed description of the parts and assemblies of the product, usually by prescribing compliance with a set of drawings, and (2) those performance requirements and corresponding tests and inspections necessary to assure proper fabrication, adjustment, and assembly techniques. Tests normally are limited to acceptance tests in the shop environment. Selected performance requirements in the normal shop or test area environment and verifying test therefore may be included. Preproduction or periodic tests to be performed on a sampling basis and requiring service, or other, environment may reference the associated development specification. Product fabrication specifications may be prepared as Part II or a two-part specification (see Two-part Specifications, Product Specification and Specifications) when the procuring activity desires a close relationship between the performance and fabrication requirements. [3]

Type C5 - Computer program product specification. (See MIL-STD-490, Appendix XIII for outline of form.) A Type C5 specification is applicable to the production of computer programs and specifies their implementing media, i.e. punch tape, magnetic tape, disc, drum, etc. It does not cover the detailed requirements for material or manufacture of the implementing medium. When two-part specifications (See Two-part Specification) are used Type B5 shall form Part I and Type C5 shall form Part II. Specifications of this type shall provide a translation of the performance requirements into programming terminology and quality assurance procedures necessary to assure production of a satisfactory program. [3] (See also Product Specification and Specifications)

UPDATES - This relationship indicates that a function on the path updates internal system information as part of its activities. (See also Information Flow)

USES - This relationship indicates that a function on the path uses external information (external input) or internal system information (internal input) in order to accomplish its activities. (See also Information Flow)

Using Command (Also called Using Agency and Using Activity) - The command primarily responsible for operational employment of a system. (See also Implementing Command and Supporting Command) [8]

UTILIZES - This relationship indicates that function on a path is dependent upon the use of one or more other functions in order to accomplish its activities. A single function or sequence of functions may be defined once and utilized as frequently as necessary in the control flow without having to be redefined (replicated) for each use. (See also Control Flow).

Validation - Comprises those evaluation, integration, and test activities carried out at the system level to ensure that the system being developed satisfies the requirements of the system specification. While the validation process has significant software implications, a software validation process, distinct from the system validation process, cannot be isolated since all evaluation and test activities that make up validation are focused at the system level. [7],[2]

Validation Phase - The period when major program characteristics are refined through extensive study and analyses, hardware development, test and evaluations. The objective is to validate the choice of alternatives and to provide the basis for determining whether or not to proceed into Full-Scale Development. (See AFR 800-2 and AFSCP 800-3) [1] (see also Acquisition Life Cycle)

Verification - The iterative process of determining whether the product of each step of the Computer Program Configuration Item (CPCI) development process fullfills all of the requirements levied by the previous step. [7],[2]

Work Breakdown Structure (WBS) - A work breakdown structure is a product-oriented family tree composed of hardware, software, services, and other work tasks which result from project engineering efforts during the development and production of a defense material item and which completely defines the project/program. A WBS displays and defines the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product. (MIL-STD-881, MIL-STD-480) [1]

DEFINITION REFERENCES

The following references are the sources of many of the preceding definitions.

[1] ESD Program Manager's Handbook, Directorate, Acquisition Support, USAF Headquarters, Electronic Systems Division (AFSC), May 1976.

[2] G. Neil, and H. I. Gold, Software Acquisition Management Guidebook: Software Quality Assurance, ESD-TR-77-255 (DDC/NTIS Accession No. AD-A047318), USAF Electronic Systems Division, August 1977.

[3] MIL-STD-490, Specification Practices, 30 October 1968.

[4] MIL-STD-480, Configuration Control-Engineering Changes, Deviations and Waivers, 30 October 1968.

[5] MIL-STD-483, Configuration Management Practices for Systems, Equipment, Munitions, and Computer Programs, 31 December 1970.

[6] AFR 800-3, Engineering for Defense Systems, 1 June 1976.

[7] H. Bratman, and M. C. Finfer, Software Acquisition Management Guidebook: Verification. ESD-TR-77-263 (DDC/NTIS Accession No. AD-A048577), USAF Electronic Systems Division, June 1976.

[8] W. L. Schoeffel, An Air Force Guide to Software Documentation Requirements, ESD-TR-76-159 (DDC/NTIS Accession No. AD-A027051), USAF Electronic Systems Division, June 1976.

[9] Management Guide to Avionics Software Acquisition, Software Acquisition Process, Vol. II, ASD-TR-76-11, USAF Aeronautical Systems Division, June 1976.

[10] MIL-STD-499A (USAF), Engineering Management, 1 May 1974.

[11] J. B. Glore, Software Acquisition Management Guidebook: Life Cycle Events, ESD-TR-77-22 (DDC/NTIS Accession No. AD-A037115), USAF Electronic Systems Division, February 1977.

[12] D. H. Johnson and John J. Marciniak, "The Systems Operational Concept - A Computer Resources Viewpoint," presented at the National Aerospace and Electronics Conference (NAECON '78), Vol. 3, pp. 1316-1321, 18 May 1978.

[13] AFR 57-1 (draft), Statement of Operational Need, 8 June 1978.

LIST OF ABBREVIATIONS

Abbreviation	Definition
ADP	Automated Data Processing
AF	Air Force
AFR	Air Force Regulations
AFSC	Air Force Systems Command or Air Force Specialty Codes
AFSCM	Air Force Systems Command Manual
CADSAT	Computer-Aided Design and Specification Analysis Tool
CDRL	Contract Data Requirements List
C^3	Command, Control, and Communications
CI	Configuration Item
CPC	Computer Program Component
CPCI	Computer Program Configuration Item
CPDP	Computer Program Development Plan
DCP	Decision Coordinating Paper
DID	Data Item Description
DoD	Department of Defense (also DOD)
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DSARC	Defense Systems Acquisition Review Council
DT&E	Development Test and Evaluation
ECM	Electronic Countermeasures
ECCM	Electronic Counter-Countermeasures
ECP	Engineering Change Proposal
EMC	Electromagnetic Compatibility
EMP	Electromagnetic Pulse
ESD	Electronic Systems Division
EW	Electronic Warfare
FORTRAN	Formula Translation (an HOL)
FOT&E	Follow-on Operational Test and Evaluation
FQR	Formal Qualification Review
FQT	Formal Qualification Test
FSD	Full-Scale Development
GFP	Government-Furnished Property
HOL	Higher Order Language
HQ	Headquarters
I/O	System External and Internal Inputs and Outputs
IOT&E	Initial Operational Test and Evaluation
MIL-STD	Military Standard
MTBF	Mean-Time-Between-Failure
MTBM	Mean-Time-Between-Maintenance
MTTR	Mean-Time-To-Repair
O&M	Operations and Maintenance
OSD	Office of the Secretary of Defense
OT&E	Operational Test and Evaluation
PMD	Program Management Directive

LIST OF ABBREVIATIONS (cont'd)

Abbreviation	Definition
PMP	Program Management Plan
PO	Program Office (see also SPO)
PQT	Preliminary Qualification Test
PSL/PSA	Problem Statement Language/Problem Statement Analyzer
QA	Quality Assurance
RADC	Rome Air Development Center
R&D	Research and Development
RFP	Request for Proposal
ROC	Required Operational Capability
SEMP	System Engineering Management Plan
SE/TD	System Engineering/Technical Direction
SOC	Systems of Operational Concept
SON	System Operational Need
SOW	Statement of Work
SPO	System Program Office (see also PO)
SS	System Specification
S/V	Survivability/Vulnerability
TEMP	Test & Evaluation Master Plan
TR	Technical Report
USAF	United States Air Force
WBS	Work Breakdown Structure